Chapter 5: Hydrology of the South Florida Environment

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SUMMARY

Given hydrology's significance to the entire South Florida environmental restoration and water management functions of the South Florida Water Management District (District or SFWMD), it is presented as a separate chapter in the *2005 South Florida Environmental Report – Volume I*. This chapter updates hydrologic data and analysis from the *2004 Everglades Consolidated Report* and has expanded coverage to address the hydrology of the area within the District's boundaries, providing a more comprehensive overview of the South Florida hydrology. In this chapter, the hydrology of the major hydrologic systems from the Upper Kissimmee Chain of Lakes in the north to the Everglades National Park (Park or ENP) in the south is presented. Rainfall, potential evapotranspiration, water levels, inflows and outflows are presented for Water Year 2004 (WY2004) (May 1, 2003 to April 30, 2004). Hydrologic conditions in this water year were compared with the previous water year, WY2003. Historical hydrologic data also were analyzed and compared with the current and previous Water Year's hydrology. This chapter does not include comparisons of current hydrology with predevelopment hydrology.

Overall, no extreme hydrologic event (e.g., El Niño, La Niña, hurricanes, or drought) occurred during WY2004 on this area. For the current reporting year, rainfall in the Upper Kissimmee, Lower Kissimmee, and Lake Okeechobee rainfall areas was close to average. The east coast and the Everglades National Park had lower than average rainfall and the west coast had higher than average rainfall. Potential evapotranspiration or evaporation from lakes, wetlands, and impoundments was close to the expected District-wide average of 52.6 inches.

During WY2004, monthly average water levels in most of the lakes in the Upper Chain of Lakes (Lake Alligator, Lake Myrtle, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, and Lake Tohopekaliga) were generally close to WY2003 levels and current regulation schedules except for Lake Tohopekaliga. In the current water year, ecological drawdown was implemented on Lake Tohopekaliga and deviations were made from the regular regulation schedule. A water level decline of 4.5 feet (ft) was observed between December 2003 and April 2004. Lake Kissimmee average water level in WY2004 [50.24 ft National Geodetic Vertical Datum (NGVD)] was lower than that of WY2003, whereas Lake Okeechobee average water level (15.62 ft NGVD) was higher than the WY2003 average water level of 14.76 ft NGVD. Lake Istokpoga average water level in WY2004 (39.06 ft NGVD) was close to the previous water year average water level.

The average water level in Water Conservation Area 1 (WCA-1) for WY2004 was 16.61 ft NGVD. It was slightly higher than the WY2003 average water level of 16.51 ft NGVD and higher than the historical average of 15.63 ft NGVD. In the current reporting year, the average water level in Water Conservation Area 2 (WCA-2) was 12.40 ft NGVD. It was higher than the

WY2003 average water level of 12.17 ft NGVD but lower than the historical average of 12.58 ft NGVD. During WY2004, the average water level in Water Conservation Area 3 (WCA-3) was 10.30 ft NGVD. It was higher than the WY2003 water level average of 10.07 ft NGVD as well as the historical average of 9.50 ft NGVD. In WY2004, the average water level in the Park at site P33 was 6.68 ft NGVD. It was higher than the WY2003 water level average of 6.35 ft NGVD as well as the historical average of 5.96 ft NGVD. Average water level in the Park at site P34, for WY2004, was 3.09 ft NGVD. It was also higher than the WY2003 average water level of 2.53 ft NGVD as well as the historical average of 2.04 ft NGVD.

During WY2004, surface water outflow through Lake Kissimmee was 1,193,153 acre-feet (ac-ft) and Lake Istokpoga discharge was 401,631 ac-ft. Lake Okeechobee inflows were 2,920,448 ac-ft and outflows were 2,617,958 ac-ft. Discharge into the southern Indian River Lagoon and St. Lucie estuary was 1,103,338 ac-ft with 688,528 ac-ft discharged through the St. Lucie canal outflow structure S-80. Discharge into the Caloosahatchee Estuary through the S-79 structure was 2,445,277 ac-ft. Inflows to WCA-1 were 334,957 ac-ft and outflows were 269,603 ac-ft. In this reporting period, both inflows and outflows were about half as much as the WY2003 flows. WY2004 inflows to WCA-2 were 520,641 ac-ft and outflows were 749,663 ac-ft. Inflows were lower and outflows were higher in WY2004 than WY2003. WY2004 inflows to WCA-3 were 1,053,423 ac-ft and outflows were 1,221,322 ac-ft. These inflows were about the same as WY2003 inflows but higher than WY2003 outflows. Inflows to the Park were 1,251,807 ac-ft, which were higher than those in WY2003.

INTRODUCTION

The South Florida Water Management District (District or SFWMD) area extends from Orlando in the north to the Florida Keys in the south (**Figure 5-1**). The South Florida water management system comprises of lakes, impoundments, wetlands, and canals that are managed under a water management schedule based on flood control, water supply, and environmental enhancement. The general surface water direction is from the north to the south, but there are also water supply and coastal discharges to the east and the west. The major hydrologic components comprise of the Upper Kissimmee Chain of Lakes, the Lower Kissimmee, Lake Okeechobee, Lake Istokpoga and Surface Water Management Basin, the Everglades Agricultural Area (EAA), the Caloosahatchee Basin, St. Lucie Basin and the Everglades Protection Area (EPA).

The Upper Kissimmee Chain of Lakes (Lake Myrtle, Lake Alligator, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, Lake Tohopekaliga, and Lake Kissimmee) are the principal sources of inflow to Lake Okeechobee. On the average, 48 percent of inflow into Lake Okeechobee is through the Kissimmee River (C-38 canal) (Abtew et al., 2002). The Upper Kissimmee watershed has an area of approximately 1,620 square miles. The Lower Kissimmee River Basin (727 square miles) also contributes inflows to Lake Okeechobee. Additional inflows to Lake Okeechobee are from the Lake Istokpoga Surface Water Management Basin (418 square miles), Fisheating Creek, the Taylor Creek-Nubbin Slough Basin, reverse flow from the Caloosahatchee River, the St. Lucie Canal, and reverse flow from the Everglades Agricultural Area (EAA) (Abtew et al., 2002). Lake Istokpoga is a 43 square-mile shallow lake, with outflow through structure S-68 into the Surface Water Management Basin.

Lake Okeechobee is the center of the South Florida hydrologic system with an area of 730 square miles and a mean depth of 8.86 feet (ft). Since 1931, the average water level elevation is 14.1 ft National Geodetic Vertical Datum (NGVD) with a maximum 18.77 ft NGVD set on November 2, 1947. The lowest water level in record for the lake was 8.97 ft NGVD, set on

Figure 5-1. Major hydrologic components of the South Florida water management system.

May 24, 2001 during the 2000–2001 drought. The annual average inflow to Lake Okeechobee (1972–2001) is about 2 million acre feet (ac-ft), while the average outflow is about 1.3 million. Outflows are mainly through the south, southeast, and southwest structures. About 10 percent of the outflow is lake water flow through the EAA, with most of it reaching the EPA (Abtew and Khanal, 1994; Abtew et al., 2002).

The Everglades Agricultural Area is the main source of surface water inflow into the EPA. On the average, about 900,000 ac-ft of water is discharged from the EAA to the south and southeast, mostly discharging into the EPA (Abtew and Khanal, 1994; Abtew and Obeysekera, 1996).

The Everglades Protection Area begins at the southern and eastern edges of the EAA and extends south to Florida Bay. The EPA comprises several defined regions: the Arthur R. Marshall Loxahatchee National Wildlife Refuge, which contains Water Conservation Area 1 (WCA-1) (221 sq mi); Water Conservation Areas 2A and 2B (WCA-2A and 2B) (210 sq mi); Water Conservation Areas 3A and 3B (WCA-3A and 3B) (915 sq mi); Everglades National Park (Park or ENP) (2,150 sq mi); and Florida Bay, as shown in Redfield et al. (2003). The extent and components of the EPA are depicted in **Figure 5-1**. The EPA receives additional surface water inflows from the urban areas in the east, from the southeast and northwest sources currently identified as non-Everglades Construction Project (non-ECP) stormwater flows. Surface water flow into and out of the EPA is determined by weather-related factors and multi-objective water management decisions that include fixed regulation schedules, deviations, agreements, obligations, and emergency management. Emergency management includes flood control during high rainfall events, water supply during drought periods, saltwater intrusion, and environmental issues. From north to south, flood control and water supply are managed through systems of canals, stormwater detention ponds, lakes, impoundments, and water control structures. The major hydrologic components of the District are depicted in **Figure 5-1**.

The South Florida Water Management District has an intensive hydrologic monitoring network and database. The District's hydrometeorologic database, DBHYDRO, also stores data from other agencies such as the U.S. Geological Survey (USGS), The U.S. Army Corps of Engineers (USACOE), National Oceanographic and Atmospheric Administration (NOAA), Everglades National Park (Park or ENP), Florida Forestry Service (FFS), Florida Department of Environmental Protection (FDEP) and others. Details of hydrometeorologic monitoring by the SFWMD are presented in Crowell and Mtundu (2000).

HYDROLOGY

RAINFALL

South Florida is a high-rainfall region, with frontal, convective, and tropical system-driven rainfall events. The heaviest rains in South Florida are produced by mesoscale convective systems – extra-tropical in the dry season and tropical in the rainy season (Rosenthal, 1994). In Central and South Florida (excluding the Florida Keys), 57 percent of total summer rainfall falls on undisturbed sea breeze days, 39 percent on disturbed days, and 4 percent on highly disturbed days (Burpee and Lahiff, 1984). The annual average rainfall on the entire region managed by the SFWMD is 52.8 inches (Ali and Abtew, 1999). The SFWMD area is divided into 14 rainfall areas for operational purposes. **Figure 5-2** depicts these rainfall areas and the ENP. Average annual rainfall for each rainfall area and the ENP is depicted in **Figure 5-3**. The source of annual rainfall statistics is from Ali and Abtew (1999), except for the Big Cypress Basin and WCA-3, which are

Figure 5-2. Rainfall areas of the South Florida Water Management District (District or SFWMD).

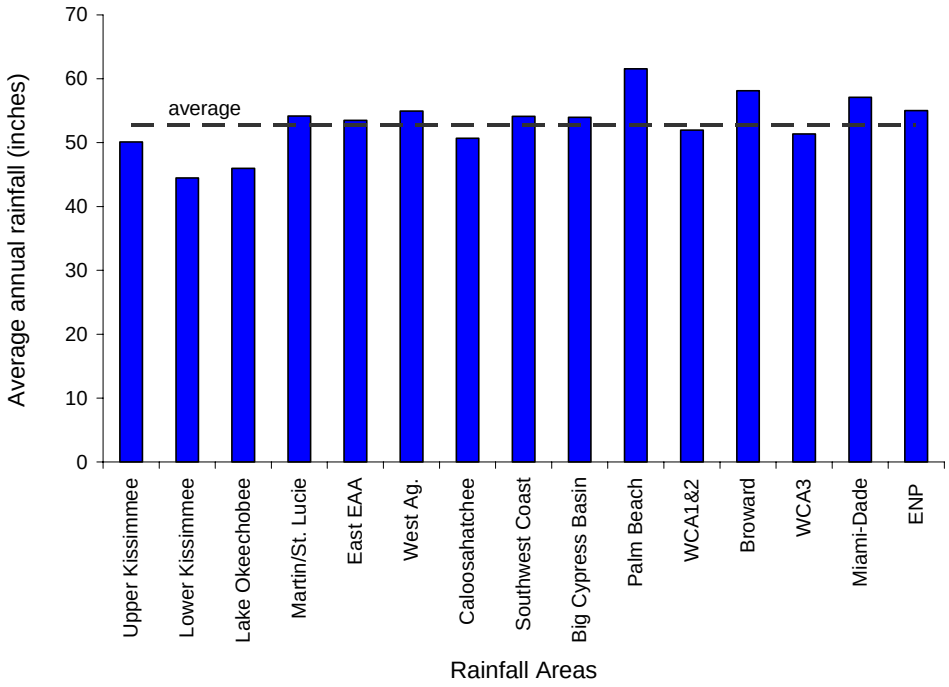

Figure 5-3. Average annual rainfall for SFWMD and each rainfall area.

from the meteorological analysis section of the District's Operations Division. The annual basin rainfall for the ENP was estimated from average annual rainfall isohyetal map for Central and South Florida (MacVicar, 1981) and from basin rainfall statistics (Sculley, 1986). The areal rainfall statistics were developed from varying lengths of record for each rainfall station and from a varying number of rainfall stations. The periods of record were 1900–1995 (Ali and Abtew, 1999), 1901–1980 (MacVicar, 1981), 1941–1985 (Sculley, 1986), and 1971–2000 (SFWMD).

In the South Florida Water Management District area, generally June is the wettest month and December is the driest month. The wet season runs from June through October and accounts for 66 percent of annual rainfall (Abtew et al., 2002). The dry season runs from November through May. During El Niño years, high rainfall falls in the dry season, resulting in water level rises and discharge through canals (Huebner, 2000). Extreme hydrometeorological and related events have significant effects on the region. El Niño conditions, hurricanes, and tropical systems are associated with high-rainfall events or seasons, and La Niña conditions and drought events result in dry conditions. El Niño occurs about once every three to four years (Huebner, 2000). Tropical systems are a frequent occurrence. The general area of the District has been affected by 42 hurricanes, 32 tropical storms, and 9 tropical cyclones (a term used before modern hurricane categories were established) from 1871–1999 (Abtew and Huebner, 2000). Other conditions, such as local convective systems and regional frontal systems also have been associated with high rainfall events.

Historically, the Palm Beach rainfall area has the highest annual rainfall, followed by the Broward and Miami Dade rainfall areas. The District's east coast receives higher rainfall levels than the inland and west coast of the District area. Even during drought years, there were cases where the coastal rainfall was close to the average. Because there are no large impoundments in the coastal area, runoff is discharged to the Atlantic Ocean.

Dry periods in Florida result from stable atmospheric conditions that are often associated with high-pressure systems (Winsberg, 1990). These conditions can occur in any season, but are most common in winter and spring. Droughts are characterized by a significant decline in annual rainfall. They also promote the development and spread of wildfires. In Central and South Florida, severe droughts were reported in 1932, 1955–1957, 1961–1963, 1971–1972, 1973–1974, 1980–1982, 1985, 1988–1989, 1990, and 2000–2001 (Abtew et al., 2002). A minimum of one severe drought can be expected every 10 years. Historical droughts are identified by the historical Palmer Drought Severity Index, annual rainfall, lake water levels, groundwater levels, stream flow, and wildfire records. Fire is an important ecological process in the Everglades (Wu et al., 1996). Frederick and Ogden (2001) reported that pulsed breeding of long-legged wading birds takes place following severe drought in the Everglades. Everglades water-level decline of one standard deviation below the mean is stated as the hydrological indicator.

During Water Year 2004 (WY2004) (May 1, 2003 to April 30, 2004), rainfall data were obtained from the District's Operation and Maintenance Department rainfall report. Everglades National Park area rainfall was estimated as the average of four stations: S174_R, TAMIAMIR_R, S332_R, and Chekika. Generally for WY2004, the east coast had deficit rainfall and the west coast had higher than average rainfall. West Ag. (54.9 inches) and Broward (57.8 inches) rainfall areas had close to average rainfall. Upper Kissimmee (51.5 inches), Lower Kissimmee (47.3 inches), Caloosahatchee (60.1 inches), Big Cypress Basin (59.1 inches) and the Southwest Coast (67.3 inches) had higher than average rainfall. Lake Okeechobee (43.1 inches), East EAA (43.6 inches), WCA-1 and WCA-2 (44.1 inches), WCA-3 (46.9 inches), Martin St. Lucie (47.9 inches), Palm Beach (50.4 inches), Miami-Dade (54.9 inches), and Everglades National Park (47.4 inches) had below average rainfall. **Figure 5-4** shows the WY2004, WY2003, and historical annual average rainfall for each rainfall area. **Figures 5-5** through **5-19**

show the WY2004, WY2003, historical monthly rainfall, and estimated potential evapotranspiration (ETp) for each rainfall area. For areas such as lakes, water conservation areas and wetlands that are wet all year round, the ETp approximates the actual ET. The deviation in water year rainfall from the historical average is shown in the legends.

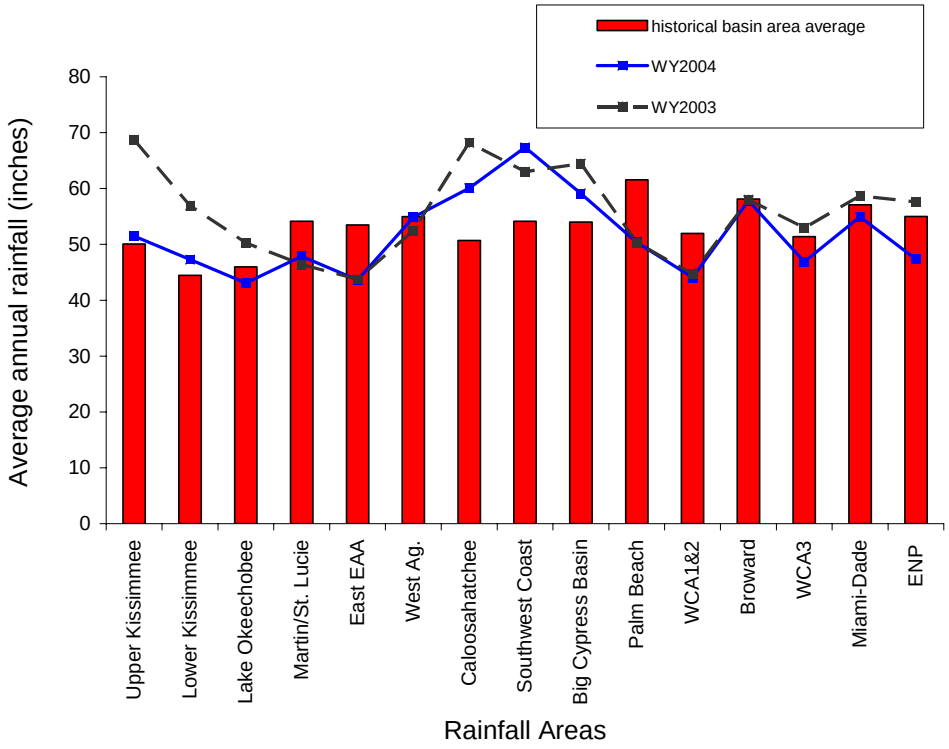

Figure 5-4. WY2004, WY2003, and historical average annual rainfall for each rainfall area.

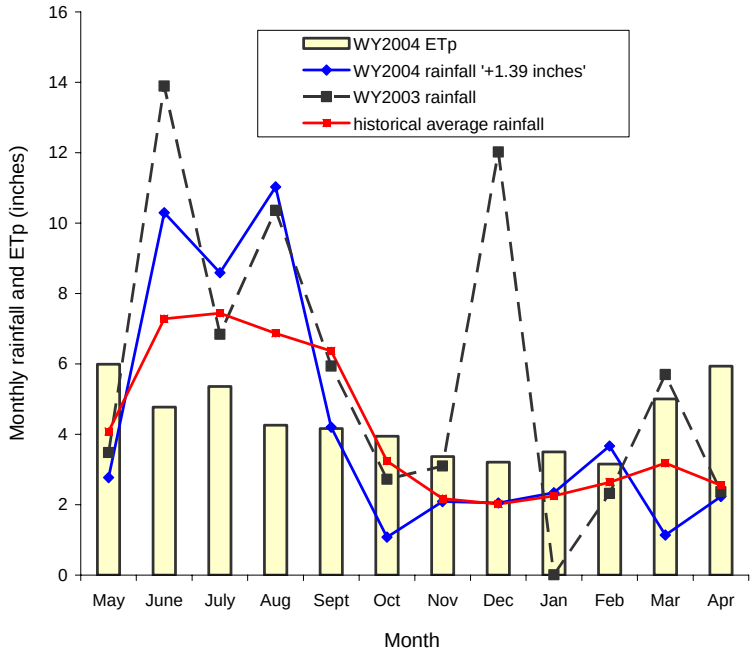

Figure 5-5. Monthly rainfall and potential evapotranspiration (ETp) for Upper Kissimmee rainfall area.

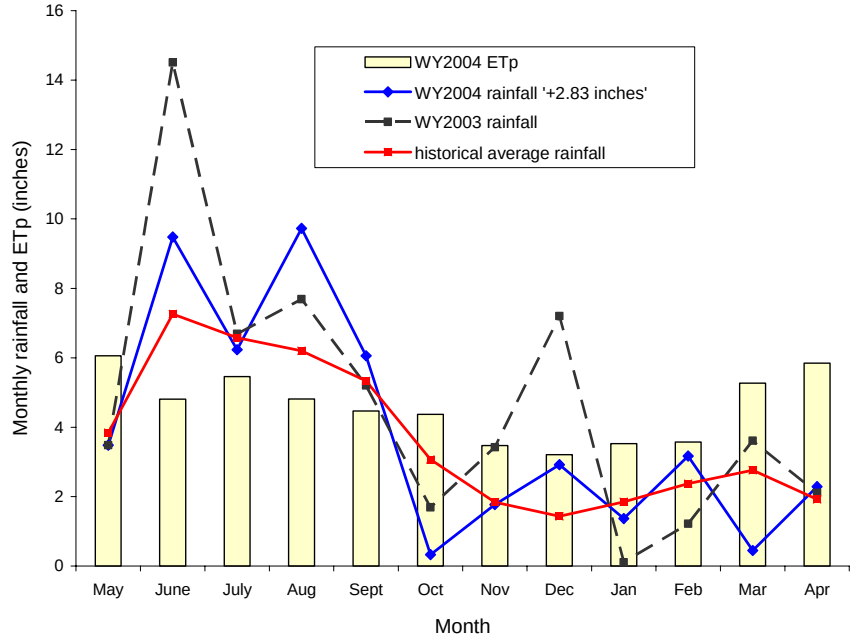

Figure 5-6. Monthly rainfall and ETp for Lower Kissimmee rainfall area.

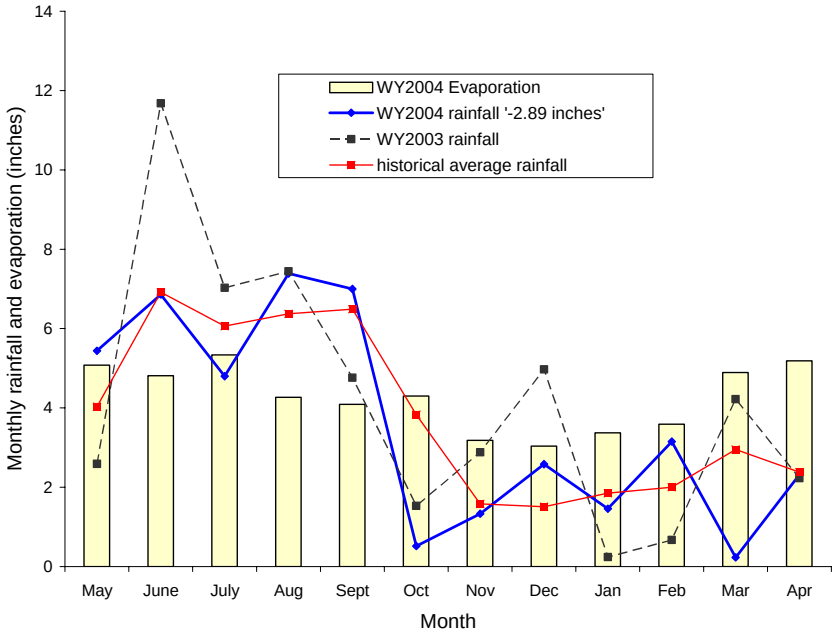

Figure 5-7. Monthly rainfall and ETp for Lake Okeechobee rainfall area.

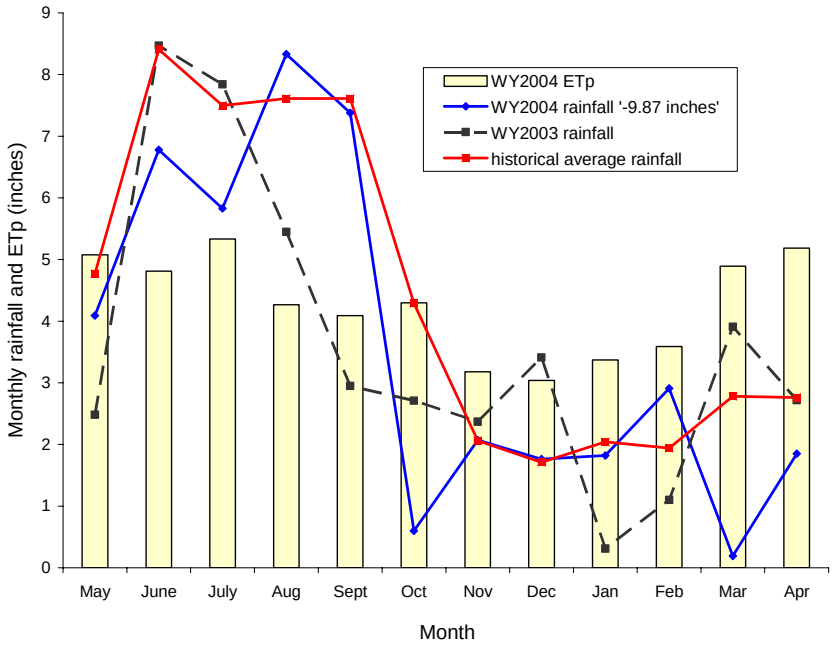

Figure 5-8. Monthly rainfall and ETp for East Everglades Agricultural Area (EAA) rainfall area.

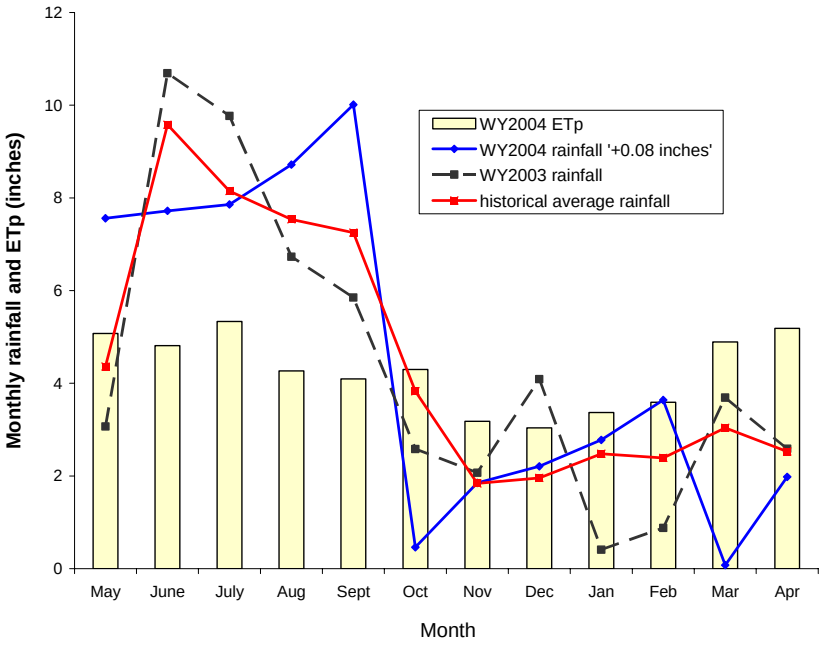

Figure 5-9. Monthly rainfall and ETp for West Ag. rainfall area.

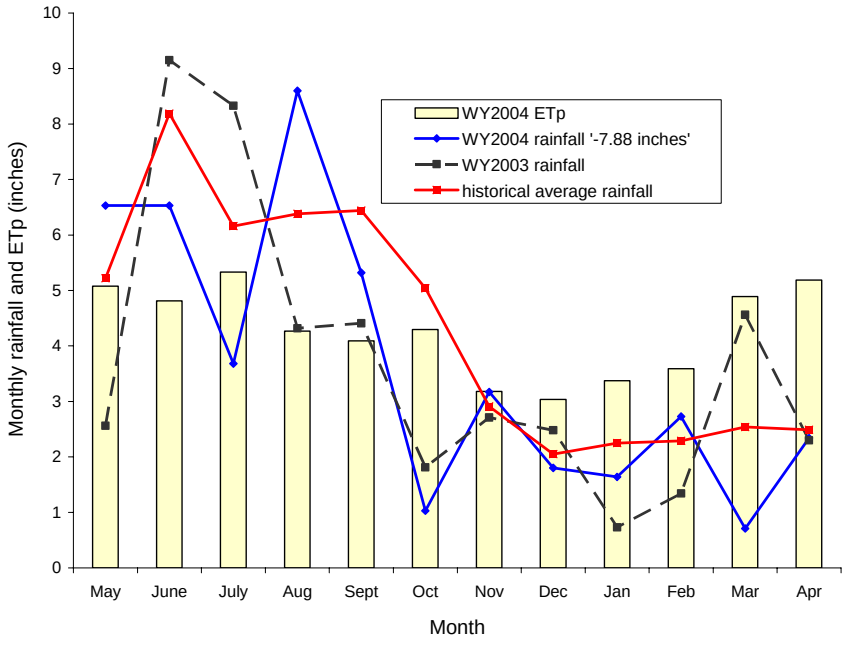

Figure 5-10. Monthly rainfall and ETp for Water Conservation Areas 1 and 2 (WCA-1 and WCA-2) rainfall area.

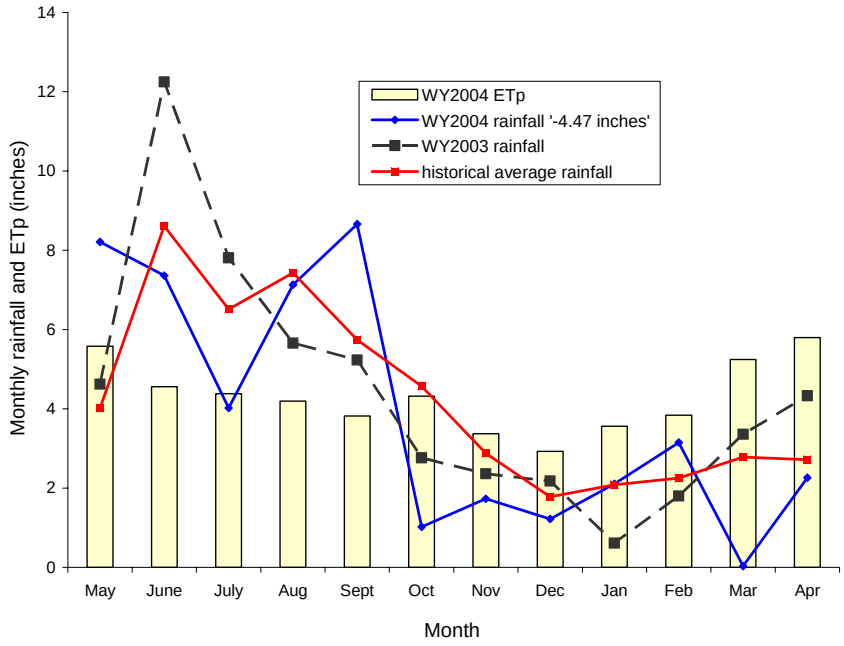

Figure 5-11. Monthly rainfall and ETp for WCA-3 rainfall area.

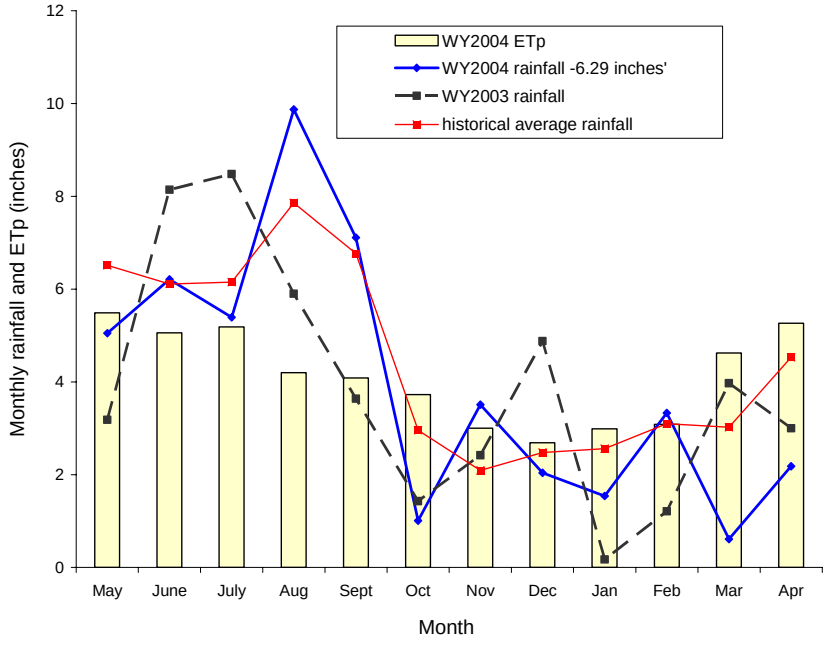

Figure 5-12. Monthly rainfall and ETp for Martin St. Lucie rainfall area.

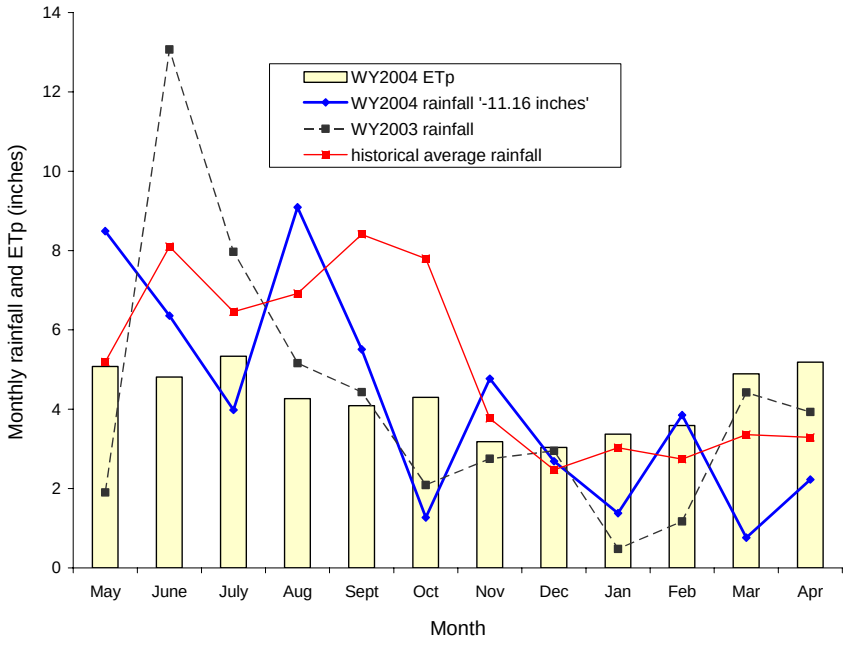

Figure 5-13. Monthly rainfall and ETp for Palm Beach rainfall area.

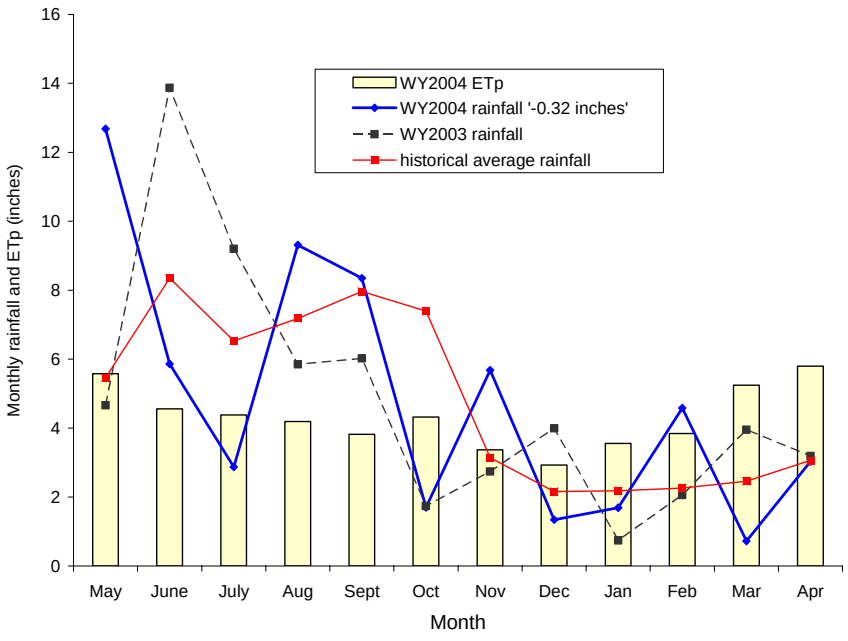

Figure 5-14. Monthly rainfall and ETp for Broward rainfall area.

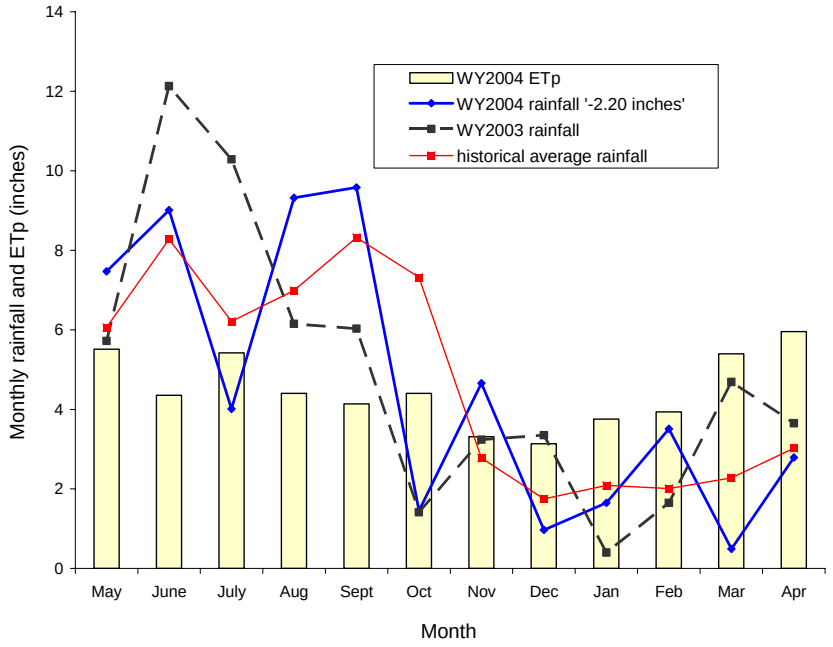

Figure 5-15. Monthly rainfall and ETp for Miami-Dade rainfall area.

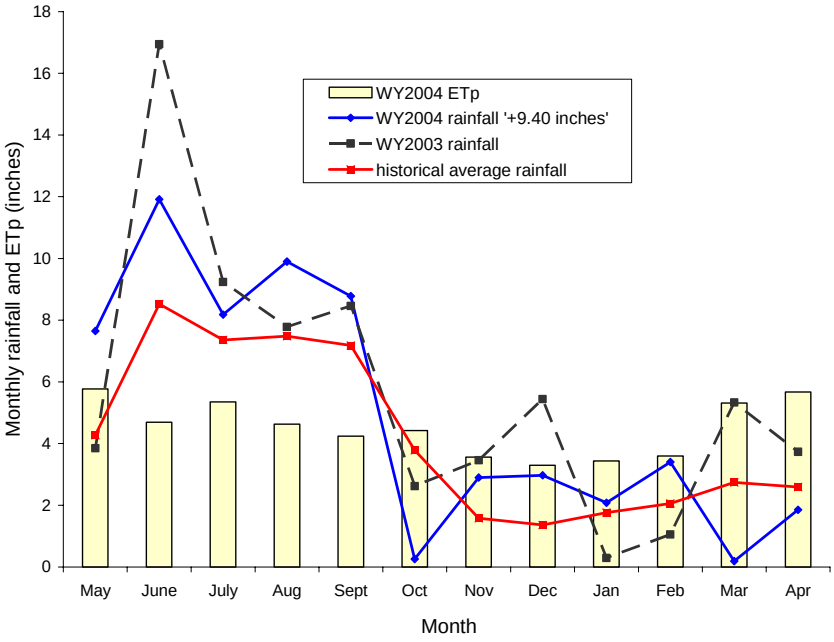

Figure 5-16. Monthly rainfall and ETp for Caloosahatchee rainfall area.

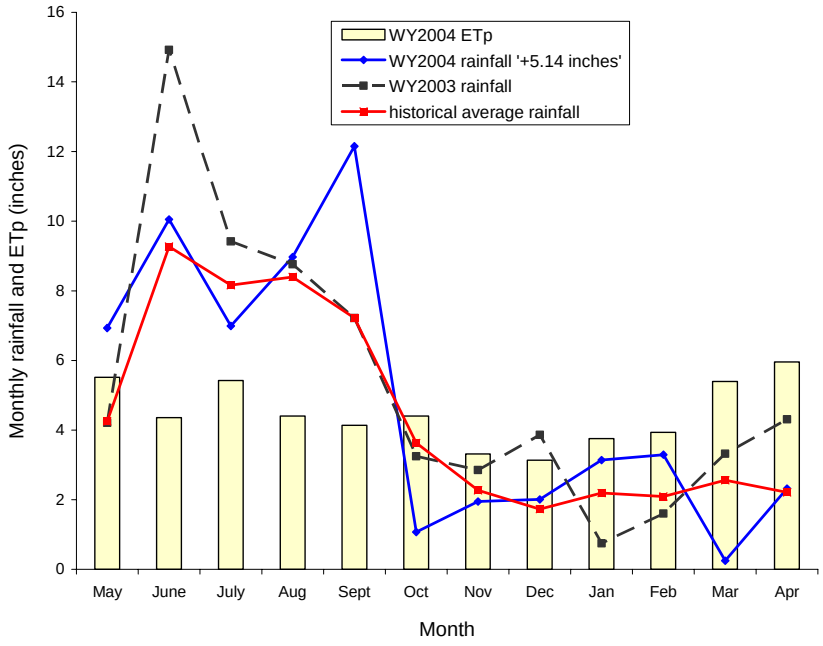

Figure 5-17. Monthly rainfall and ETp for Big Cypress Basin rainfall area.

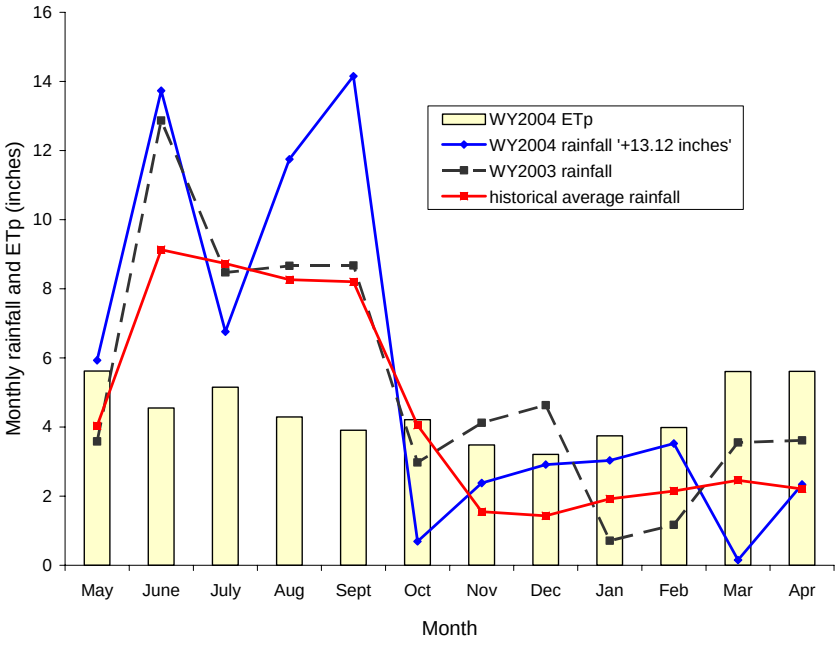

Figure 5-18. Monthly rainfall and ETp for Southwest Coast rainfall area.

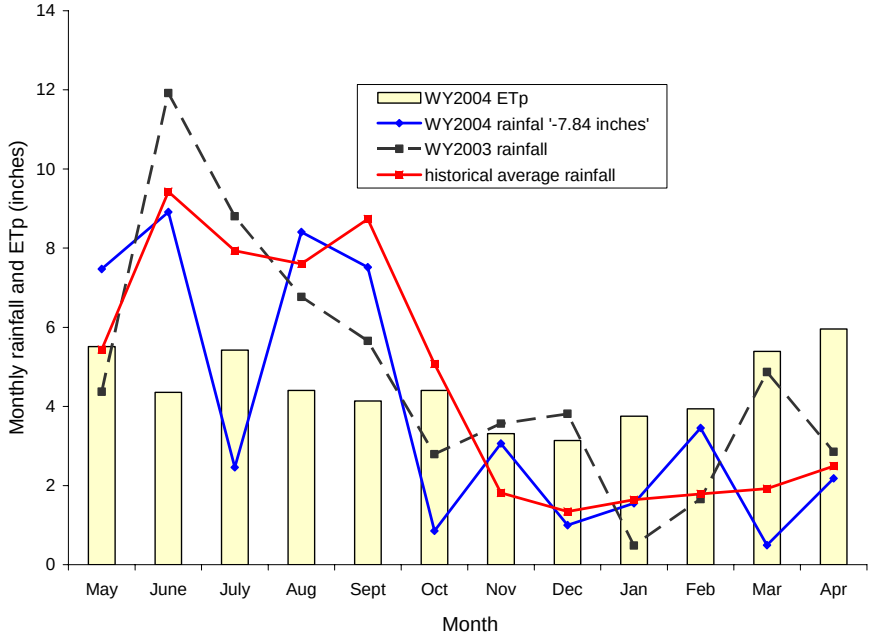

Figure 5-19. Monthly rainfall and ETp for Everglades National Park (ENP or Park).

EVAPOTRANSPIRATION

Rainfall and evapotranspiration (ET) are the main parameters in the hydrologic balance of the Everglades. The delicate balance between rainfall and ET maintains the hydrology system in either a wet or a dry condition. Evaporation from open water and transpiration from vegetation are functions of solar radiation, temperature, wind speed, humidity, atmospheric pressure, characteristics of the surrounding environment, and type and condition of vegetation. In South Florida, most of the variation in evapotranspiration is explained by solar radiation (Abtew, 1996). Various measurements and estimates of evapotranspiration have been reported in the literature for various locations in Central and South Florida. Regional estimates of evapotranspiration from open water and wetlands that do not dry out ranges from 48 inches in the northern section of the District to 54 inches in the Everglades (Abtew et al., 2003). Model estimates of ETp form SFWMD database, DBHYDRO, are depicted in **Figures 5-5** through **5-19**. The closest site to a rainfall area with available ETp data was used as estimates of ETp for the area. Potential evapotranspiration is actual evaporation for lakes, wetlands and any feature that is wet year round. Estimates for WY2004 were as follows: Upper Kissimmee, 52.7 inches; Lower Kissimmee, 54.9 inches; Lake Okeechobee, 51.1 inches; Martin St. Lucie, 49.4 inches; East EAA, 51.1 inches; West Ag., 51.1 inches; Caloosahatchee, 54 inches; Southwest Coast, 53.4 inches; Big Cypress Basin, 53.7 inches; Palm Beach, 51.1 inches; WCA-1 and WCA-2, 51.1 inches; Broward, 51.6 inches; WCA-3, 51.6 inches; Miami-Dade, 53.7 inches; and ENP, 53.7 inches.

WATER LEVELS

Upper Chain of Lakes Water Levels

Lake Alligator in the Upper Chain of Lakes has an average of 62.34 ft NGVD water level (stage) since 1993. The maximum daily average water level was 64.17 ft NGVD and the minimum was 58.13 ft NGVD. The minimum stage was reached during the 2000-2001 drought of South Florida. Daily water level observations for Lake Alligator in the last 10 years shows that the most significant change in water level occurred in 2000 and 2001, during the drought (Appendix 5-1, Figure 1). The daily average stage for WY2004 was 63.08 ft NGVD compared to 61.24 ft NGVD for WY2003. **Figure 5-20** depicts WY2004, WY2003, historical monthly average water levels and regulation schedules, as reported in the SFWMD Daily System Storage Report.

Lake Myrtle in the Upper Chain of Lakes has an average of 58.45 ft NGVD water level since 1993. The maximum daily average water level was 64.59 ft NGVD and the minimum was 58.45 ft NGVD. The minimum stage was reached during the 2000–2001 drought of South Florida. Daily water level observations for Lake Myrtle in the last 10 years shows that the most significant drop in water level occurred during the 2001 drought (Appendix 5-1, Figure 2). The daily average stage for WY2004 was 61.05 ft NGVD compared to 61.20 ft NGVD for WY2003. **Figure 5-21** depicts WY2004, WY2003, historical monthly average water levels and regulation schedules, as reported in the SFWMD Daily System Storage Report.

Lake Mary Jane in the Upper Chain of Lakes has an average of 60 ft NGVD water level (stage) since 1993. The maximum daily average water level was 61.91 ft NGVD and the minimum was 57.19 ft NGVD. The minimum stage was reached during the 2000-2001 drought of South Florida. Daily water level observations for Lake Mary Jane in the last 10 years shows that the most significant drop in water level occurred in 2001 during the drought (Appendix 5-1, Figure 3). The daily average stage for WY2004 was 60.36 ft NGVD compared to 60.30 ft NGVD for WY2003. **Figure 5-22** depicts WY2004, WY2003, historical monthly average water levels and regulation schedules, as reported in the SFWMD Daily System Storage Report.

Lake Gentry in the Upper Chain of Lakes has an average of 60.59 ft NGVD water level (stage) since 1993. The maximum daily average water level was 61.91 ft NGVD and the minimum was 57.31 ft NGVD. The minimum stage was reached during the 2000-2001 drought of South Florida. Daily water level observations for Lake Mary Jane in the last 10 years shows that the most significant drop in water level occurred in 2001 during the drought (Appendix 5-1, Figure 4). The daily average stage for WY2004 was 60.94 ft NGVD compared to 60.77 ft NGVD for WY2003. **Figure 5-23** depicts WY2004, WY2003, historical monthly average water levels and regulation schedules, as reported in the SFWMD Daily System Storage Report.

Lake East Tohopekaliga in the Upper Chain of Lakes has an average of 56.62 ft NGVD water level (stage) since 1993. The maximum daily average water level was 59.12 ft NGVD and the minimum was 54.41 ft NGVD. The minimum stage was reached in 1997. Daily water level observations for Lake East Tohopekaliga in the last 10 years are shown in Appendix 5-1, Figure 5. The daily average stage for WY2004 was 57.13 ft NGVD compared to 56.98 ft NGVD for WY2003. **Figure 5-24** depicts WY2004, WY2003, historical monthly average water levels and regulation schedules as reported in the SFWMD Daily System Storage Report.

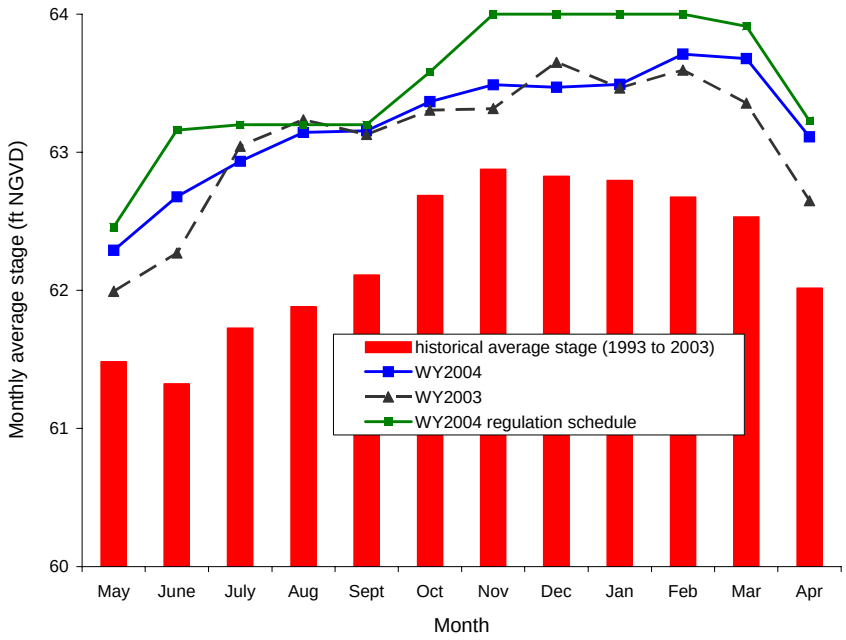

Figure 5-20. Monthly average water levels for Lake Alligator.

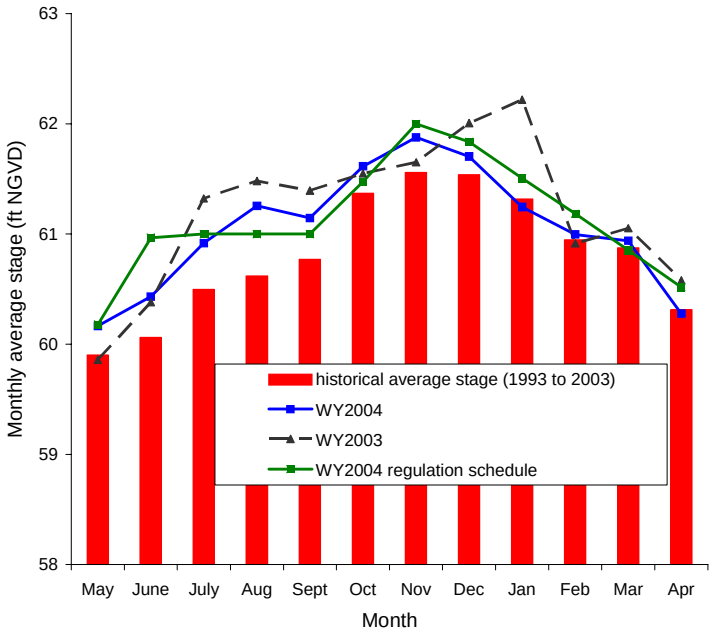

Figure 5-21. Monthly average water levels for Lake Myrtle.

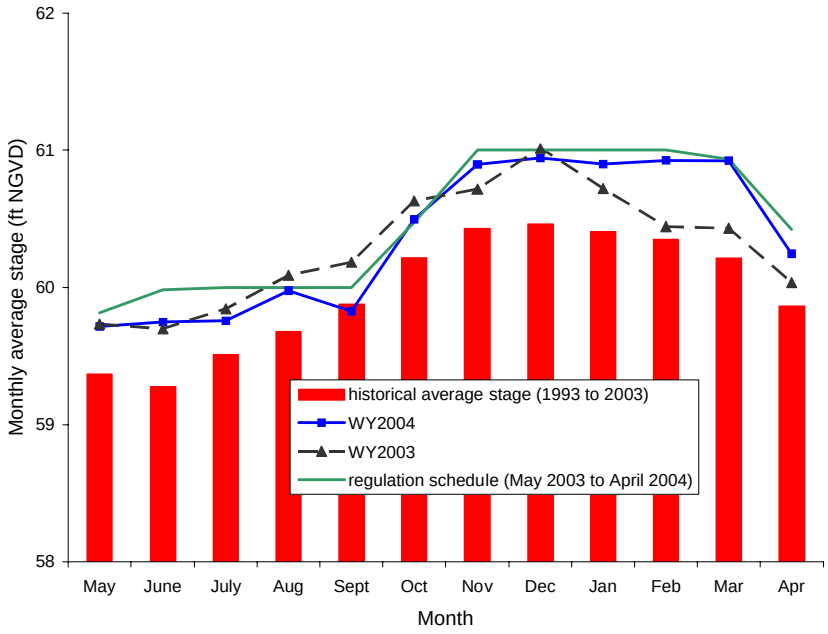

Figure 5-22. Monthly average water levels for Lake Mary Jane.

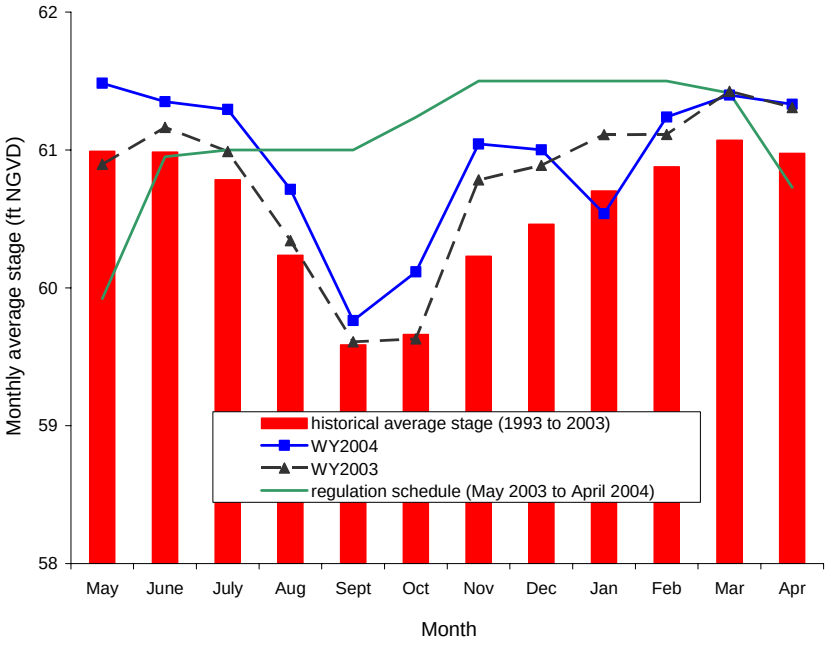

Figure 5-23. Monthly average water levels for Lake Gentry.

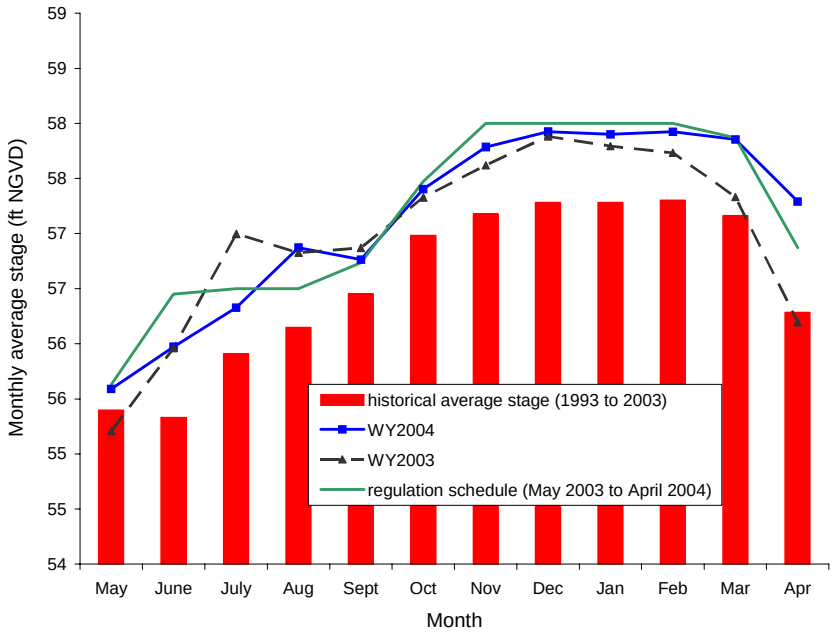

Figure 5-24. Monthly average water levels for East Tohopekaliga.

Lake Tohopekaliga in the Upper Chain of Lakes has an average of 53.66 ft NGVD water level (stage) since 1993. The maximum daily average water level was 55.77 ft NGVD and the minimum was 48.49 ft NGVD. The minimum stage was reached in 2004 following the implementation of lake drawdown. In cooperation with the Florida Fish and Wildlife Conservation Commission, the District began a planned drawdown of water levels in Lake Tohopekaliga in November 2003 to facilitate muck and tussock removal in the lake. The target drawdown water elevation of 49.0 ft NGVD was reached in late February 2004. Daily water level observations for Lake Tohopekaliga in the last 10 years shows that the most significant drop in water level occurred in 2004 during the lake drawdown (Appendix 5-1, Figure 6). The daily average stage for WY2004 was 52.16 ft NGVD compared to 53.79 ft NGVD for WY2003. **Figure 5-25** depicts WY2004, WY2003, historical monthly average water levels and regulation schedules, as reported in the SFWMD Daily System Storage Report.

Lake Kissimmee Water Levels

Lake Kissimmee covers an area of approximately 35,500 acres. The lake has an average water level (stage) of 50.38 ft NGVD based on data starting in 1929. The maximum daily average water level was 56.64 ft NGVD observed in 1953 and the minimum was 42.87 ft NGVD in 1977. The average daily water level in WY2004 was 50.24 ft NGVD, 0.39 ft. less than WY2003. **Figure 5-26** depicts monthly average water levels for WY2004, WY2003, and the period of historical record and regulation schedules, as reported in the SFWMD Daily System Storage Report. Appendix 5-1, Figure 7 shows daily water level for the period of record from 1929 to 2004.

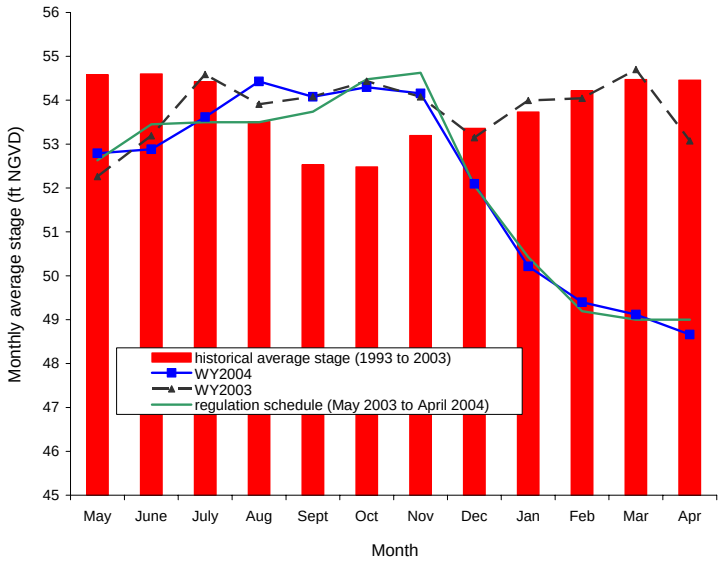

Figure 5-25. Monthly average water levels for Tohopekaliga.

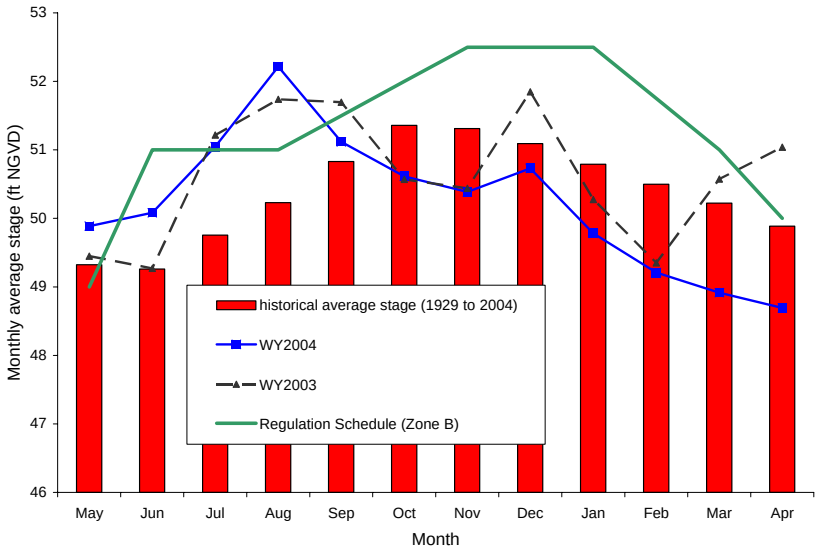

Figure 5-26. Monthly average water levels for Lake Kissimmee (site S65_H).

Lake Istokpoga Water Level

Lake Istokpoga has a surface area of approximately 27,700 acres. It has an average water level (stage) of 38.78 ft NGVD based on data since 1993. The maximum daily average water level was 39.74 ft NGVD observed in 1998 during an El Niño year and the minimum was 35.84 ft NGVD observed in 2001 during a drought year. The low water level observed in 2001 coincided with the environmental enhancement project that removed muck and tussocks from the lake bed. The average daily water level in WY2004 was 39.06 ft NGVD, 0.01 ft higher than in WY2003. **Figure 5-27** depicts monthly average water levels for WY2004, WY2003 and for the period of historical record and regulation schedules, as reported in the SFWMD Daily System Storage Report. Appendix 5-1, Figure 8 shows daily water level for the period of record from 1993 to 2004.

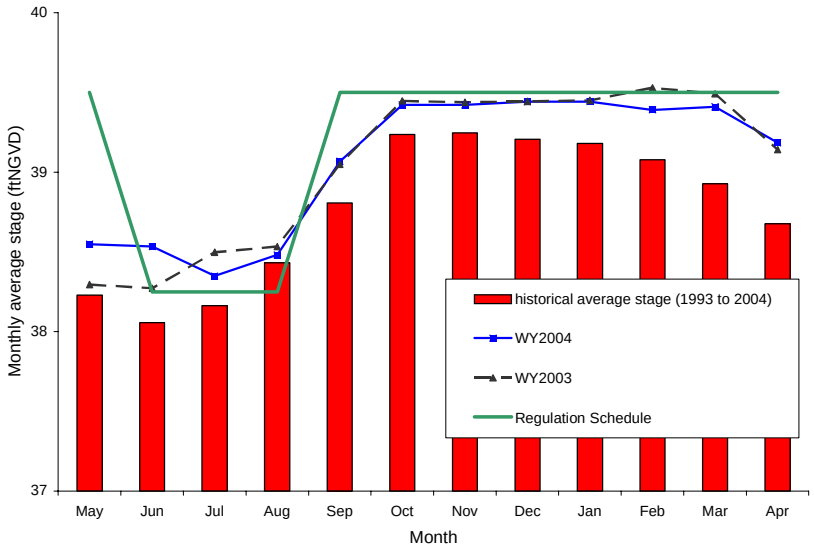

Figure 5-27. Monthly average water levels for Lake Istokpoga (site S68_H).

Lake Okeechobee Water Levels

Lake Okeechobee has an approximate surface area of 428,000 acres and an average water level (stage) of 14.13 ft NGVD based on a period of record starting in 1931. The maximum daily average water level reached18.79 ft NGVD that was observed in 1947 during a hurricane season and the minimum was 8.97 ft NGVD recorded in the 2001 drought. The average daily water level in WY2004 was 15.62 ft NGVD, 0.86 ft. higher than in WY2003. **Figure 5-28** depicts monthly average water levels for WY2004, WY2003 and for the period of historical record and regulation schedules, as reported in the SFWMD Daily System Storage Report. Appendix 5-1, Figure 9 shows daily water level for the period of record from 1931 to 2004.

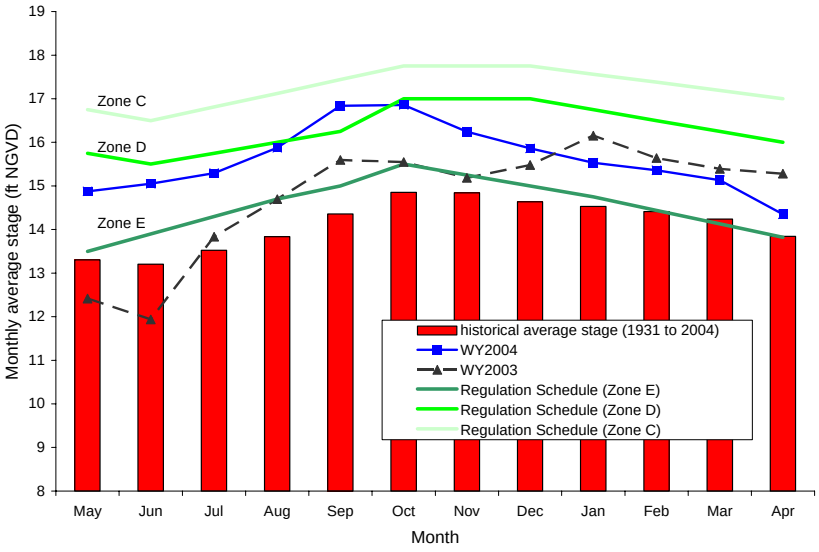

Figure 5-28. Monthly average water level for Lake Okeechobee.

Everglades Protection Area Water Levels

The Water Conservation Areas (WCAs) are shallow impoundments, with a total area of approximately 861,440 acres. Water levels in the WCAs change due to drought, rainfall, evapotranspiration, seepage, and surface water management. Surface water management in the WCAs is based on regulation schedules that vary with the time of year, hydrologic conditions, and other needs. Water Conservation Area 1 (WCA-1) is 141,440 acres in area, with a daily average water level of 15.63 ft NGVD. Maximum daily average water level of 18.19 ft NGVD was attained on October 16, 1999 during Hurricane Irene. Minimum water level of 10 ft NGVD in WCA-1 was reached on June 1, 1962, a drought year. For WY2004, average stage in WCA-1 was 16.61 ft NGVD which was slightly higher than WY2003 (16.51 ft NGVD). Maximum daily average stage was 17.23 and minimum was 15.83 ft NGVD. Daily average historical water levels are shown in Appendix 5-1, Figure 10. Comparisons of historical monthly average water level, current reporting year's average water levels, WY2003 water levels, current regulation schedule, and station elevation (Price et al., 2001) are shown in **Figure 5-29**.

Water Conservation Areas 2A and 2B (WCA-2A and 2B) combined have a total area of 133,400 acres, with 80 percent of the area in WCA-2A. WCA-2A has a historical average water level of 12.58 ft NGVD. Maximum water level of 15.64 ft NGVD was attained on November 18, 1969, and minimum level of 9.33 ft NGVD was attained on April 29, 1989 during a severe drought year. For WY2004, average stage in WCA-2 was 12.40 ft NGVD, which was higher than WY2003 (12.17 ft NGVD). The maximum daily average stage was 13.58 and the minimum was 11.23 ft NGVD. Daily average historical water levels are shown in Appendix 5-1, Figure 11. Comparisons of historical monthly average water level, current reporting year's average water levels, WY2003 water levels, current regulation schedule, and station elevation (Price et al., 2001) are shown in **Figure 5-30**.

Water Conservation Areas 3A and 3B (WCA-3A and 3B) combined have a total area of 585,560 acres in area, with 83 percent of the area in WCA-3A. WCA-3A has a historical average water level of 9.50 ft NGVD. Maximum water level of 12.79 ft NGVD was attained on January 22, 1995 during an El Niño year, and minimum level of 4.78 ft NGVD was reached on June 6, 1962, during a drought year. For WY2004, average stage in WCA-3 was 10.30 ft NGVD which was higher than WY2003 (10.07 ft NGVD). The maximum daily average stage was 11.54 and the minimum was 9.11 ft NGVD. Daily average historical water levels are shown in Appendix 5-1, Figure 12. Comparisons of historical monthly average water level, WY2004 average water levels, WY2003 water levels, current regulation schedule, and station elevation are shown in **Figure 5-31**. Site elevation is average for sites 63, 64, and 65 (Price et al., 2001; USGS, personal communication, 2000).

The Everglades National Park (ENP) is approximately 1,376,000 acres in area (Redfield et al., 2003). Water level monitoring at sites P33 and P34 has been used in previous Everglades Consolidated Reports (ECRs) as representative of slough and wet prairie, respectively (Sklar et al., 2003). Station elevations for P33 and P34 are 5.06 ft NGVD and 2.09 ft NGVD, respectively, as shown in Sklar et al. (2000). Historical water level data for sites P33 (1952–2004) and P34 (1953–2004) were obtained from DBHYDRO and from the ENP's database. For WY2004, the average stage at site P33 in ENP was 6.68 ft NGVD, which was higher than WY2003 (6.35 ft NGVD) and the historical average stage (5.96 ft NGVD).

Maximum daily average stage was 7.43 and minimum was 5.91 ft NGVD. Comparisons of historical monthly average water level, current water year's average water levels, WY2003 average water levels and station elevation are shown in **Figure 5-32.** For WY2004, the average stage at site P34 in ENP was 3.09 ft NGVD which was higher than WY2003 (2.53 ft NGVD) and the historical average stage (2.04 ft NGVD). Maximum daily average stage was 4.38 and minimum was 1.79 ft NGVD. **Figure 5-33** depicts the historical monthly average water level, the monthly average water level for WY2004, WY2003 and station elevation for station P34. WY2004 water levels were higher than previous year water levels. Daily average historical water levels for sites P33 and P34 are shown in Appendix 5-1, Figures 13 and 14.

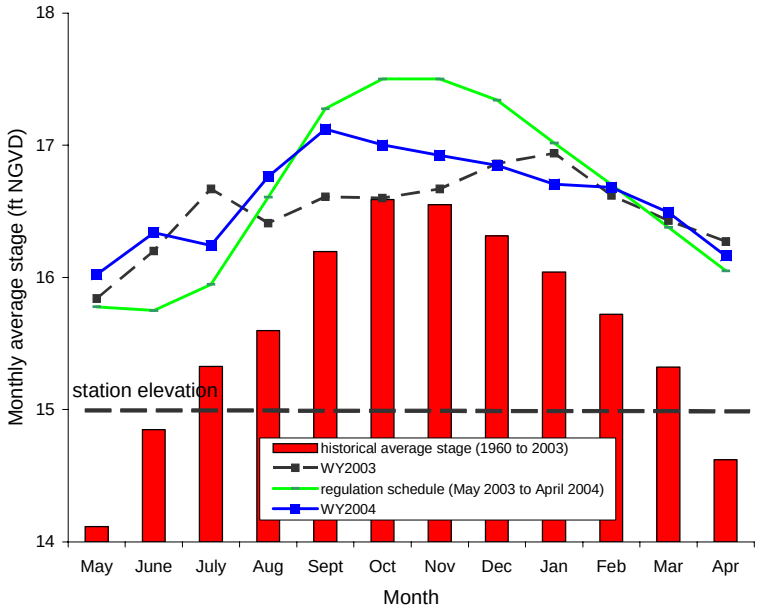

Figure 5-29. Monthly average water levels for WCA-1 (sites 1–7).

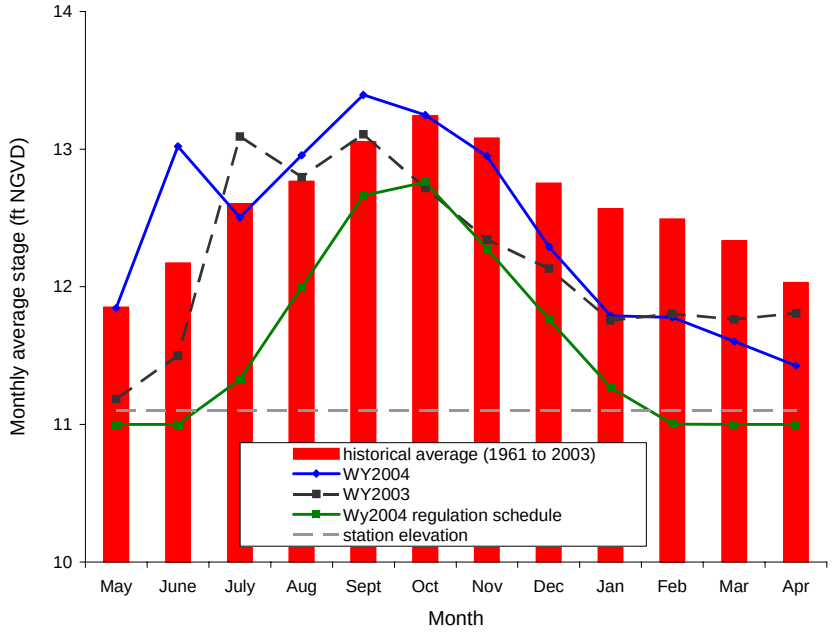

Figure 5-30. Monthly average water levels for WCA-2 (sites 2–17).

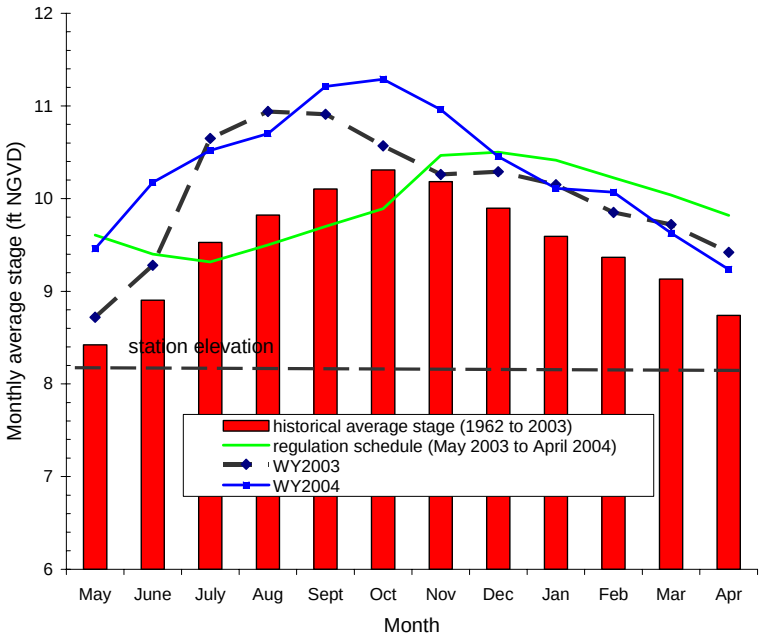

Figure 5-31. Monthly average water levels for WCA-3 (CA3AVG).

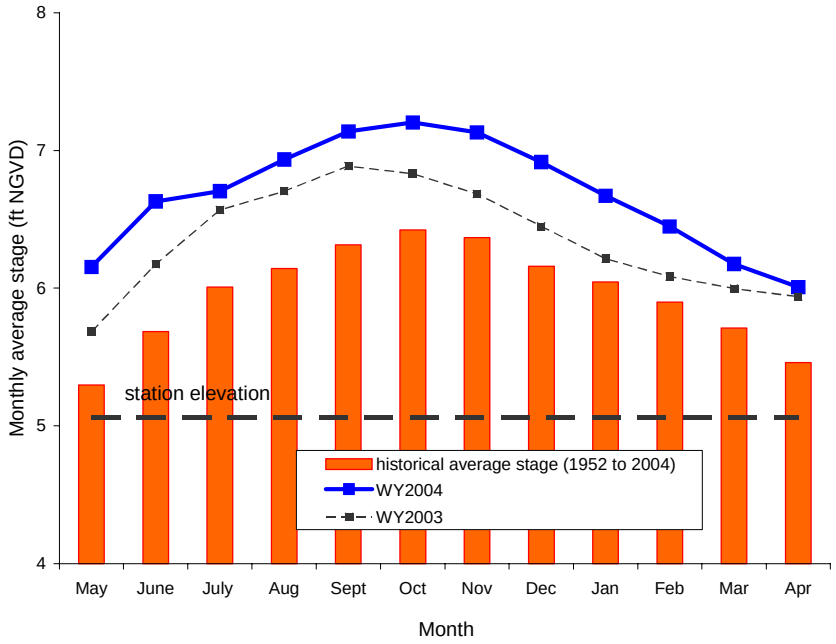

Figure 5-32. Monthly average water levels for site P33 in the ENP.

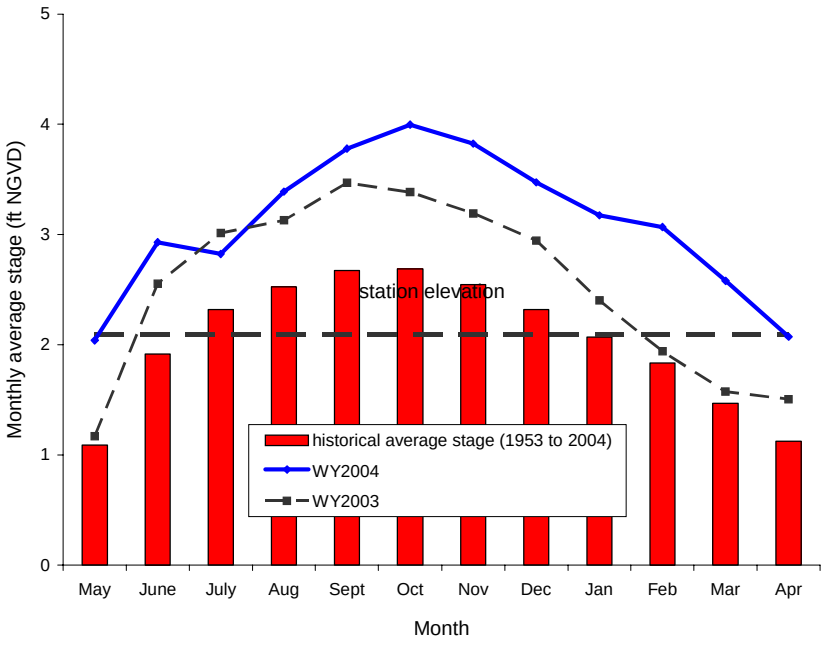

Figure 5-33. Monthly average water levels for site P34 in the ENP.

SURFACE WATER INFLOWS AND OUTFLOWS

In the South Florida water management system, surface water flow is generally regulated through water control structures and operational guidelines such as the different regulation schedules for the major lakes, impoundements and canals. The water management system is delicate system that can change from flooding state to water shortage or to environmental impact, or conversely, in a relatively short period. Water levels and flows are regulated from the Upper Chain of Lakes to the Everglades. Inflows and outflows through the major systems are presented in this chapter.

Lake Kissimmee Flows

Lake Kissimmee outflow is regulated through structure S-65. The lake's regulation schedule varies between 49 ft NGVD and 52.5 ft NGVD. Based on flow data from January 1, 1972 to April 30, 2004, the average annual outflow from Lake Kissimmee was 689,821 ac-ft. Minimum annual flow of 7,900 ac-ft occurred during the 1981 drought and the maximum annual outflow of 1,523,275 ac-ft occurred in 2003. During WY2004, the flow volume from Lake Kissimmee was 1,193,153 ac-ft, over 1.7 times the historical average flow but lower than WY2003 discharges. Total flow volume in WY2003 was 1,571,473 ac-ft. The annual flow volume in WY2004 was augmented by releases from Lake Tohopekaliga during a managed drawdown for an environmental enhancement project. **Figure 5-34** shows the average monthly outflow from Lake Kissimmee for WY2004, WY2003, and the historical period of record. Appendix 5-2, Table 1 depicts monthly flow volumes for WY2004.

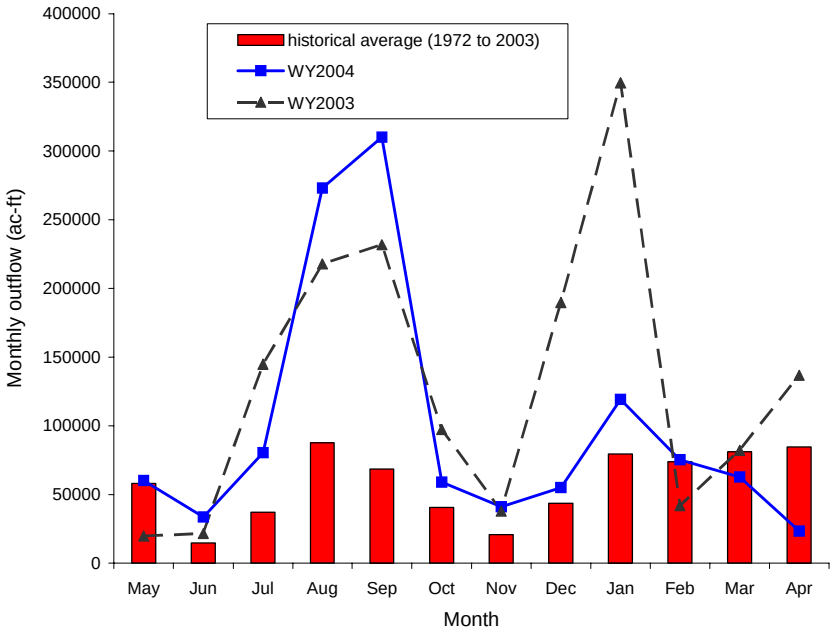

Figure 5-34. Monthly outflow from Lake Kissimmee.

Lake Istokpoga Flows

Lake Istokpoga outflow is regulated through structure S-68. The lake's regulation schedule varies between 37.0 ft NGVD and 39.5 ft NGVD. Based on flow data from January 1, 1972 to April 30, 2004, the average annual outflow from Lake Istokpoga was 212,880 ac-ft. The maximum discharge of 562,000 ac-ft occurred during the 1998 El Niño year. Minimum annual flow of 18,000 ac-ft occurred during the 1981 drought. During WY2004, the flow volume from Lake Istokpoga was 401,631 ac-ft. This was 1.9 times the average annual outflow but lower than WY2003 discharges. The outflow volume in WY2003 was 478,670 ac-ft. **Figure 5-35** shows the average monthly outflow from Lake Istokpoga for Water Years 2003, 2004 and for the historical period of record. Appendix 5-2, Table 1 depicts monthly flow volumes for WY2004.

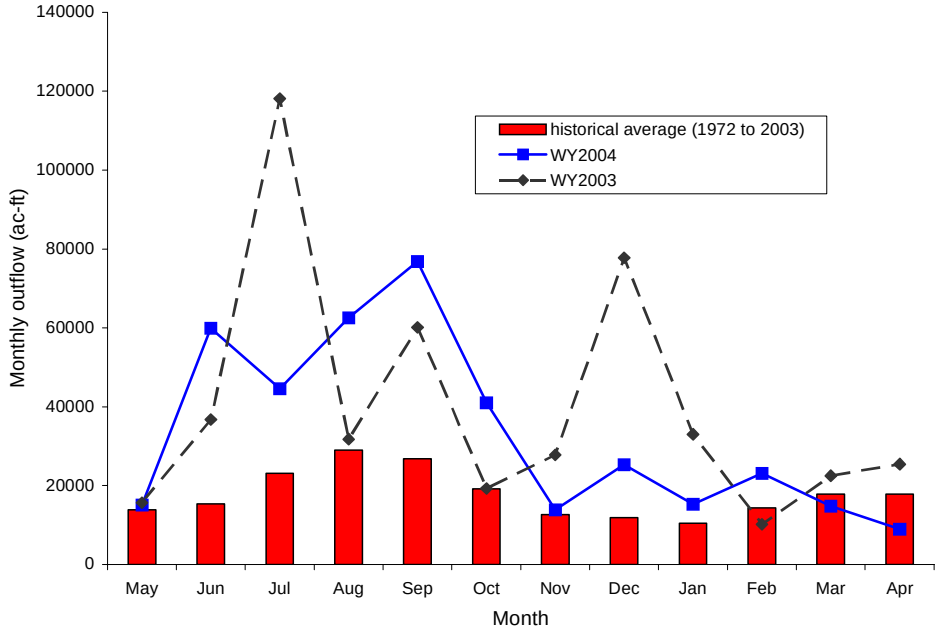

Figure 5-35. Monthly outflow from Lake Istokpoga.

Lake Okeechobee Flows

Based on flow data from January 1, 1972 to December 31, 2003 records, annual average inflow into Lake Okeechobee is 2,058,041 ac-ft, with a maximum annual inflow of 3,620,483 ac-ft in 1998 during an El Niño year. A similar volume of inflow also occurred during the 1995 El Niño year. The minimum annual inflow of 664,121 ac-ft occurred in 2000 during the drought. The volume of inflow to Lake Okeechobee in WY2004 was 2,920,448, which was higher than the historical average and lower than 3,448,689 ac-ft inflows in WY2003.

The volume of outflow from Lake Okeechobee in WY2004 was 2,617,958 ac-ft. During WY2003, 2,078,973 ac-ft of water was released from the lake. Based on data from 1972–2003, the historical annual average discharge from lake Okeechobee is 1,383,944 ac-ft, with a maximum annual discharge of 3,965,257 ac-ft in 1995 during an El Niño year. The minimum annual discharge of 349,978 ac-ft was in 1991. **Figure 5-36** shows the average monthly inflow from Lake Okeechobee for WY2003, WY2004, and the historical period of record. **Figure 5-37** shows the average monthly outflow from Lake Okeechobee for WY2004, WY2003, and the historical period of record. Appendix 5-2, Table 2 depicts monthly inflows and Appendix 5-2, Table 3 depicts outflows for Lake Okeechobee for WY2004.

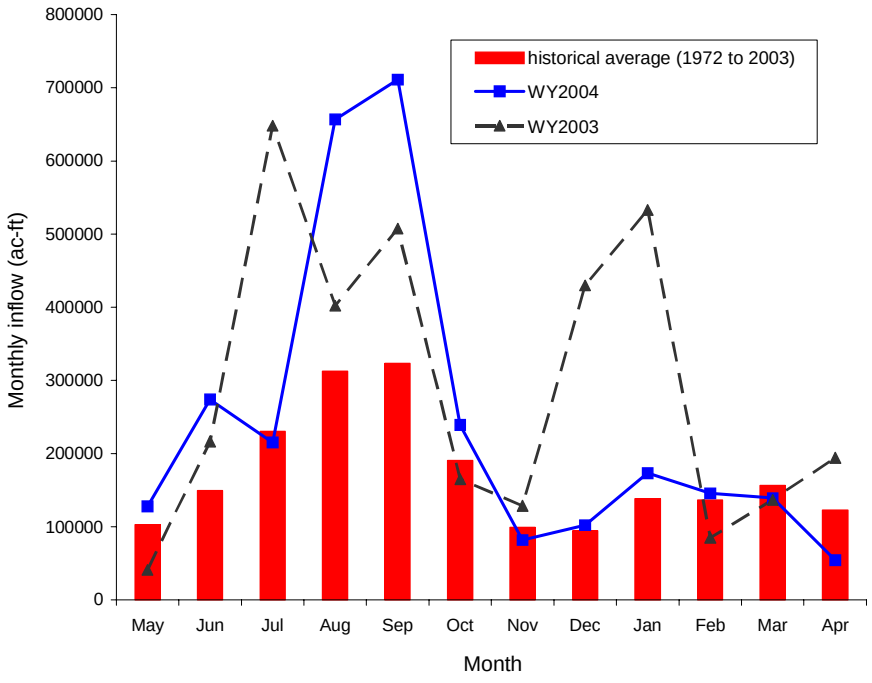

Figure 5-36. Monthly inflow to Lake Okeechobee.

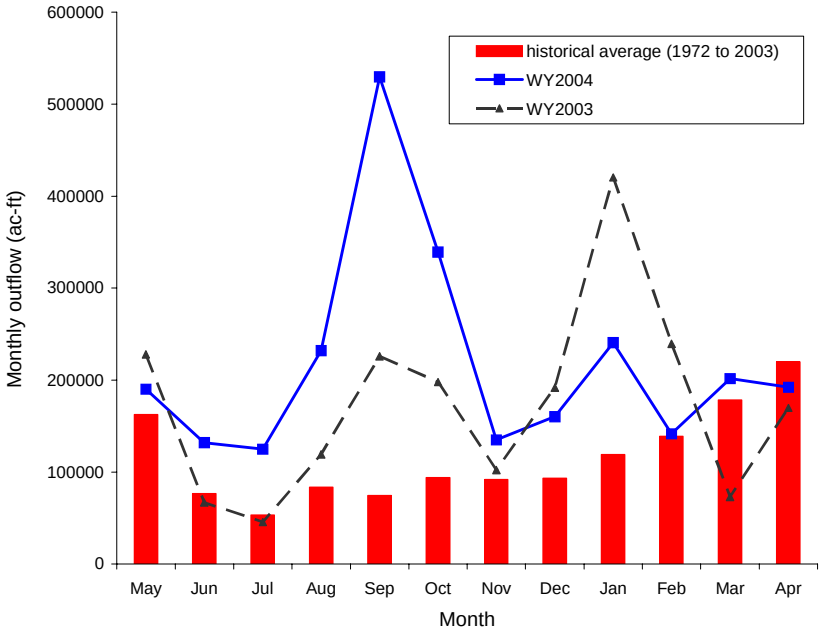

Figure 5-37. Monthly outflow from Lake Okeechobee.

St. Lucie Canal and Estuary Flows

The C-23 canal discharges at structure S-48 into the St. Lucie Estuary. During WY2004, 139,689 ac-ft of water was released at S-48, which was 5 percent more than the historical average discharge of 134,016 ac-ft (1995 to 2004). In WY2003, 125,215 ac-ft of water was discharged at S48. The C-24 canal discharges at S-49 into the northern branch of the St. Lucie Estuary. During WY2004, 155,813 ac-ft of water was discharged at S-49, 120 percent of the historical average flow (129,972 ac-ft). The C-25 canal discharges into the southern part of the Indian River Lagoon at structure S-50. In WY2004, 119,307 ac-ft of water was released at this site. This was 90 percent of the historical average discharge at S-50 (132,402 ac-ft) and 78 percent of the flow volume released in WY2003 (157,420 ac-ft).

Structure S-80 discharges through the St. Lucie Canal into the southern part of the St. Lucie Estuary. Flow at this structure comes from the C-44 basin and Lake Okeechobee. Lake Okeechobee discharge in to the St. Lucie Canal through structure S-308 was 568,505 ac-ft. In WY2004, 688,528 ac-ft was discharged at S-80. This was 31.4 percent greater than the average historical flow of 534,095 ac-ft. During WY2003, 308,612 ac-ft was discharged at the S-80 structure. **Figures 5-38** through **5-41** show the monthly outflow volumes for WY2004, WY2003, and the period of record monthly average flows at these structures. Appendix 5-2, Table 4 depicts monthly flow volumes for WY2004 for each structure.

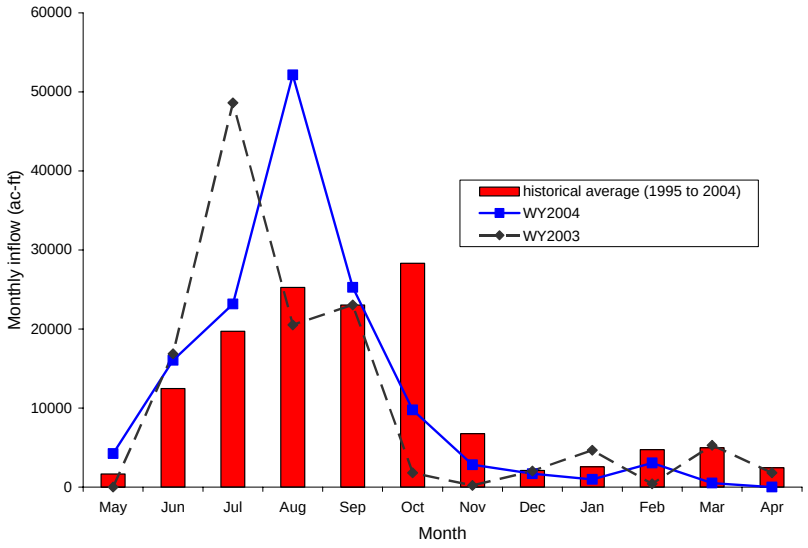

Figure 5-38. Monthly outflow from C-23 (site S-48).

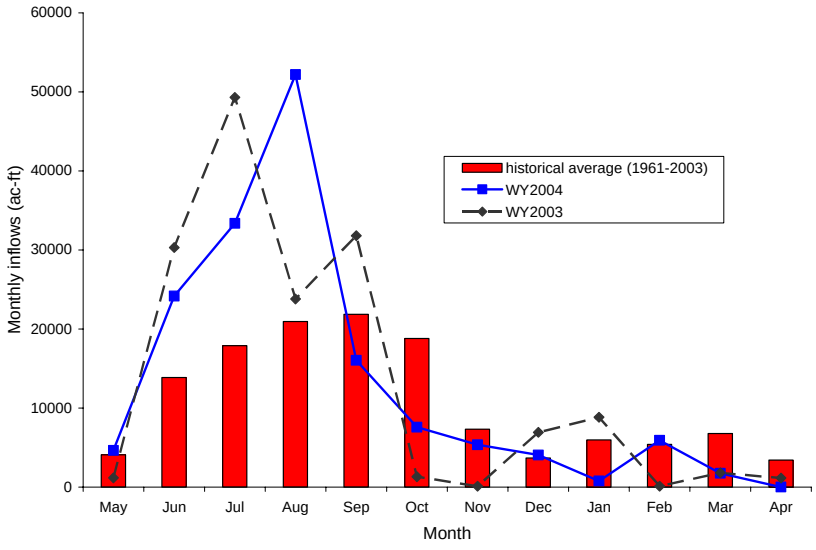

Figure 5-39. Monthly outflow from C-24 (site S-49).

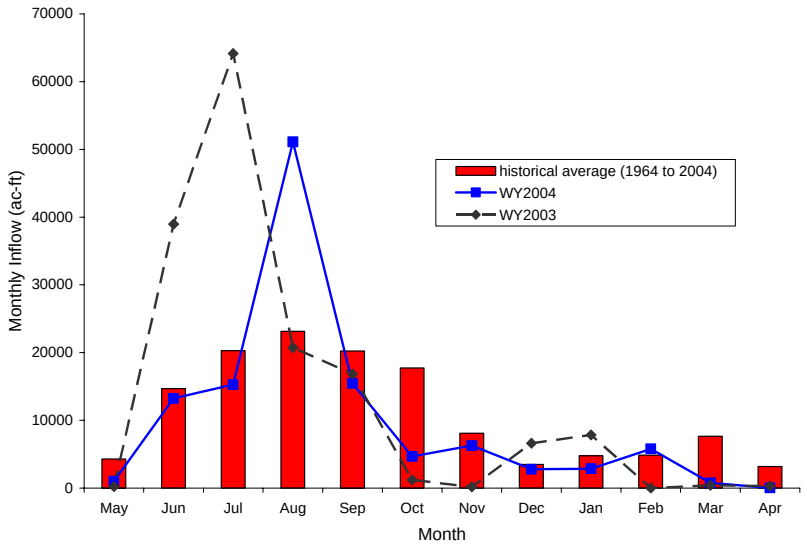

Figure 5-40. Monthly outflow from C-25 (site S-50).

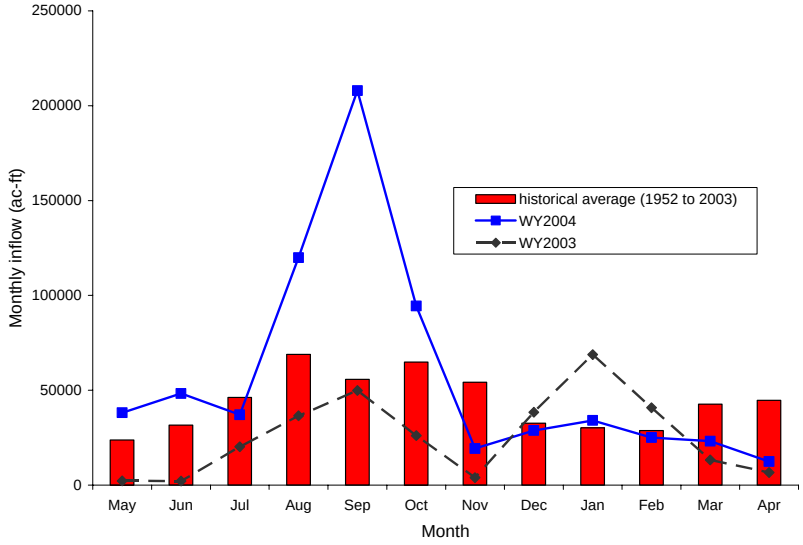

Figure 5-41. Monthly outflow from C-44 (site S-80).

Caloosahatchee River and Estuary Flows

The last structure on the Caloosahatchee River that controls discharges into its estuary is S-79. The average annual flow volume at S-79 is 1,160,378 ac-ft based on 1972 to 2003 record. In WY2004, 2,441,923 ac-ft of water was discharged through the spillway at S-79; 1,729,106 ac-ft was discharged in WY2003. For WY2004, Lake Okeechobee discharge into the Caloosahatchee River through the S-77 structure was 1,321,711 ac-ft. **Figure 5-42** shows the average monthly discharge at S-79 for WY2004, WY2003, and the historical period of record. Appendix 5-2, Table 5 in the appendix depicts the monthly flow volumes for WY2004 at this site.

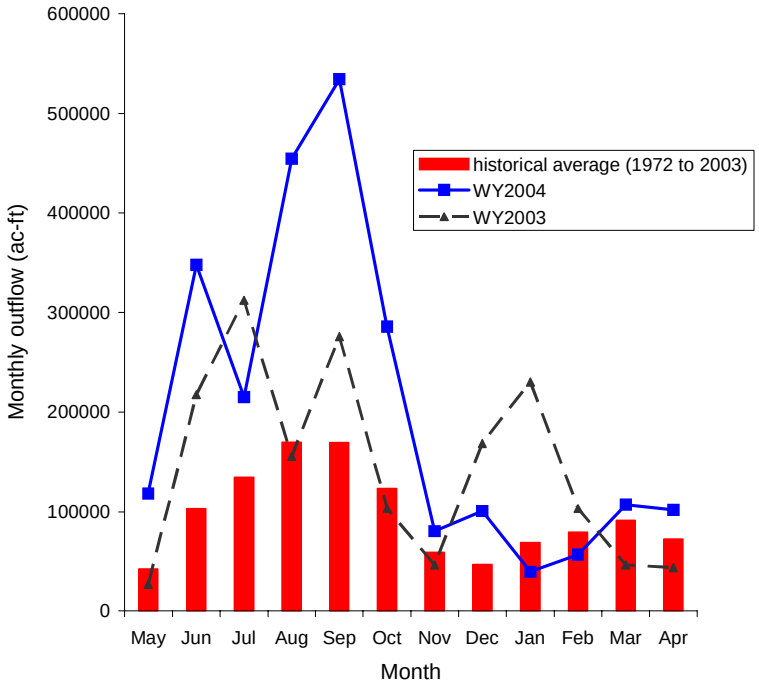

Figure 5-42. Monthly outflow at S-79 in the Caloosahatchee River.

Everglades Protection Area Flows

Inflow and outflow structures throughout the Water Conservation Areas are operated based on regulation schedules and other water management decision factors. Historical flows through each structure has varying length of period of record due to new structures coming online or existing structures that no longer contribute to the inflow and outflow of a system. The stormwater treatment structures are relatively recent additions. Time-weighted average historical inflows and outflows were computed for the period from 1978–2003. WCA-1 is regulated between 14 and 17.50 ft NGVD. The average historical inflow in WCA-1 was 381,752 ac-ft. The total inflow to WCA-1 for WY2004 was 334,957 ac-ft, which was close to the historical average and 54 percent of the WY2003 inflows (620,131 ac-ft). **Figure 5-43** depicts historical monthly average inflows, and WY2004 and WY2003 inflows to WCA-1. The major inflows (89 percent) were from STA-1W through pump stations G-310 and G-251. ACME 1 and ACME 2 sources from Wellington to the east contributed 6 percent of the total inflow. The remaining 5 percent of the flow were mainly through structures G-300 and G-301, which discharge from the inflow and distribution impoundment of STA-1W, where almost all the source is the S-5A pump station. Monthly inflows to WCA-1 by water control structure are shown in Appendix 5-2, Table 6. There was no diversion of flow from S-6 to WCA-1 through structure G-338.

Outflows from WCA-1 were mainly into WCA-2A into the Hillsboro Canal through structure S-39 (51 percent); through structures S-10A, C, D, and E (29 percent); and discharge to the Lake Worth Drainage District through structures G-94A, B, and C (10 percent). The remaining 10 percent of outflows for this reporting year were mostly backflow to the STA-1W inflow and distribution basin through structures G-300 and G-301. The total outflow for WY2004 was 269,603 ac-ft, which is 52 percent of the total outflows in WY2003 (515,099 ac-ft). The average historical monthly outflow is 535,481 ac-ft. **Figure 5-44** depicts historical monthly average outflows, and WY2004 and WY2003 outflows from WCA-1. Monthly outflows from WCA-1 by water control structure are shown in Appendix 5-2, Table 7. There were no flows through structures G-94A and G-94B.

The total inflow to WCA-2 for WY2004 was 520,641 ac-ft, compared to 692,989 ac-ft for WY2003 and 657,929 ac-ft historical average. The major inflows (55 percent) were from STA-2 through pump station G-335. WCA-1 discharges through the S-10A, C, D, and E structures are inflows to WCA-2A (15 percent). Thirty percent of the inflow was from the EAA through the S-7 structure. Inflows through structure G-339, a bypass structure at STA-2, were minimal. **Figure 5-45** depicts historical monthly average inflows, and WY2004 and WY2003 inflows into WCA-2. Monthly inflows to WCA-2 by water control structure are shown in Appendix 5-2, Table 8.

Outflows from WCA-2 are primarily into WCA-3A through structures S-11A, B, and C (54 percent); into the North New River Canal through structure S-34 (20 percent); discharge to the North New River Canal through structure S-143 (6 percent); and discharge to canals 13 and 14 through structure S-38 (19 percent). The remaining 1 percent of outflow for this reporting year was backflow to the EAA through the S-7 structure and backflow through the G-339 spillway. The total outflow for WY2004 was 749,663 ac-ft, which is 141 percent of the total outflows in WY2003 (533,400 ac-ft). The average historical monthly outflow is 682,530 ac-ft. **Figure 5-46** depicts historical monthly average outflows, and WY2004 and WY2003 outflows from WCA-2. Monthly outflows from WCA-2 by water control structure are shown in Appendix 5-2, Table 9.

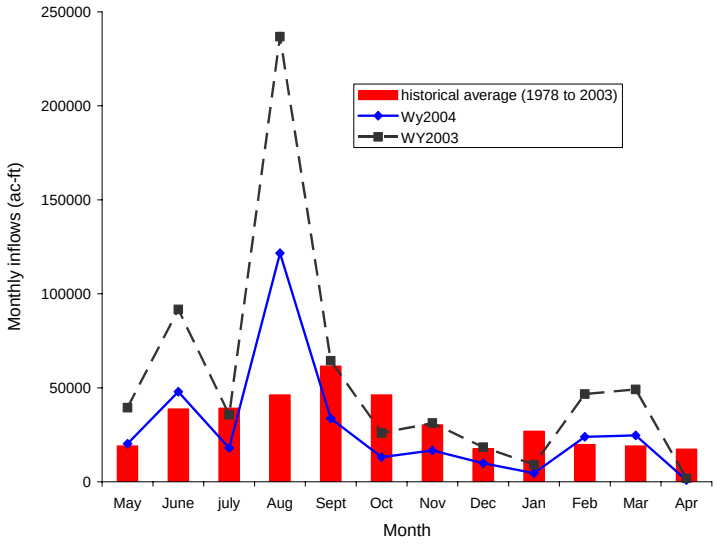

Figure 5-43. Monthly inflows into WCA-1.

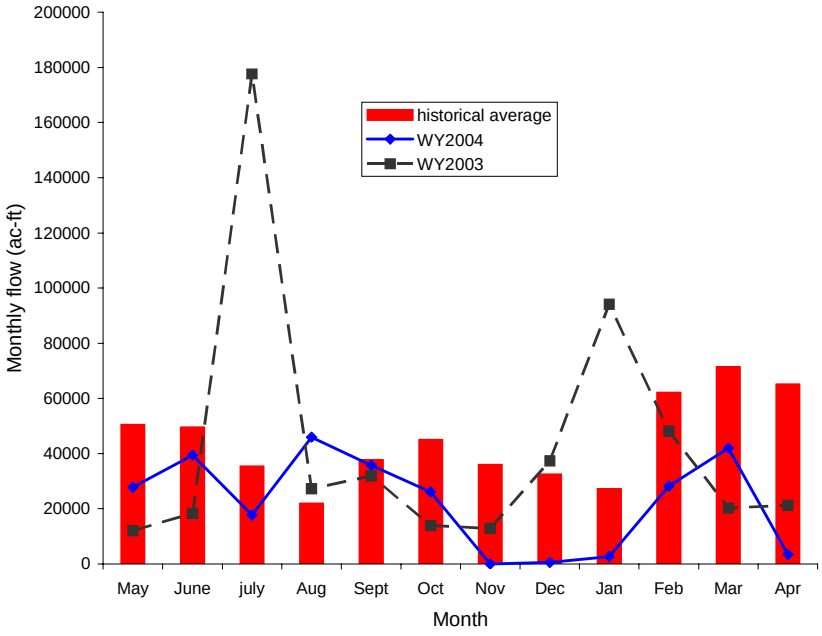

Figure 5-44. Monthly outflows from WCA 1.

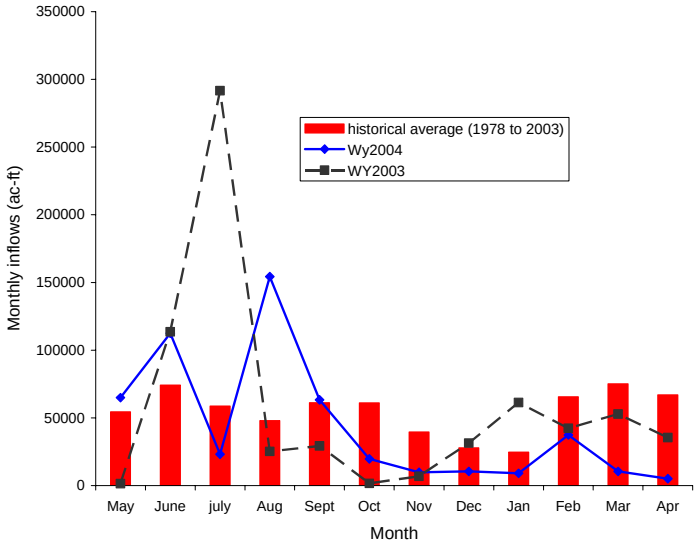

Figure 5-45. Monthly inflows into WCA-2.

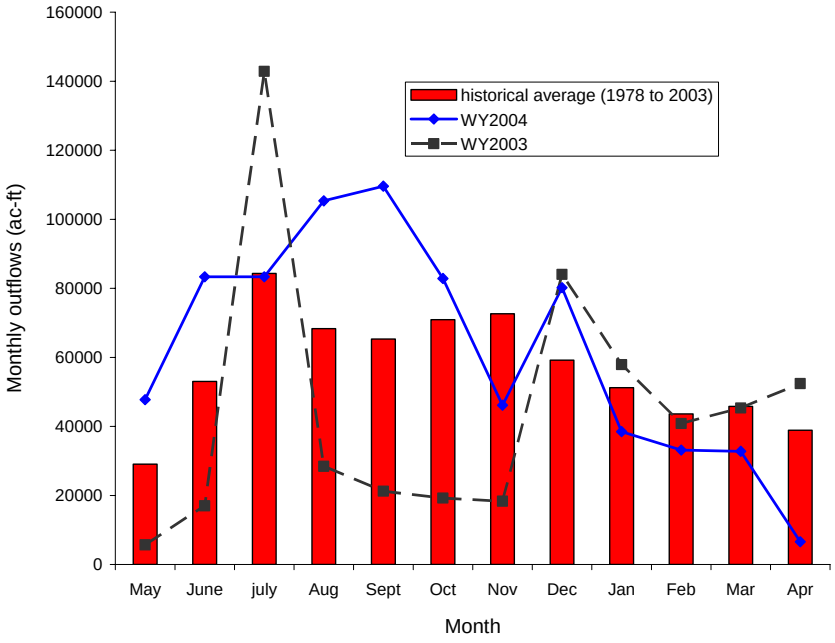

Figure 5-46. Monthly outflows from WCA-2.

Similar to WY2003 inflows (1,073,727 ac-ft), the total inflow to WCA-3 was 1,053,423 ac-ft during WY2004. The historical average inflow is 1,213,727 ac-ft. The major inflows were through S-11A, B, and C (38 percent) from WCA-2; mostly from the EAA through structures S-8 and S-150 (34 percent). Discharges from the east through structure S-9 accounted for 14 percent. The S-140 structure to the northwest contributed 13 percent of the inflow to WCA-3A. Minor inflows were through structures G-69 and S-142. There are ungauged potential inflows to WCA-3A through the L-4 borrow canal breach into the L-3 extension canal. The breach has a bottom of 150 ft at an elevation of 3.0 ft NGVD (SFWMD, 2002). **Figure 5-47** depicts historical monthly average inflows, and WY2004 and WY2003 inflows into WCA-3. Monthly inflows to WCA-3 by water control structure are shown in Appendix 5-2, Table 10.

Outflows from WCA-3A are mainly into the Everglades National Park through structures S-12A, B, C, D and E (72 percent). S-333 discharged 14 percent, with potential directions of flow to south and east Miami-Dade County, Shark River Slough, and Taylor Creek of the ENP. Discharges into the North New River Canal through structure S-142 accounted for 8 percent of the total outflow and S31 discharge was 4 percent of the total outflow. There are minor outflows through structures S-344, S-30 and G-69. The total outflow for WY2004 was 1,221,322 ac-ft, which is 132 percent of the total outflows in WY2003 (924,089 ac-ft). The average historical monthly outflow is 886,055 ac-ft. **Figure 5-48** depicts historical monthly average outflows, and WY2004 and WY2003 outflows from WCA-3. Monthly outflows from WCA-3 by water control structure are shown in Appendix 5-2, Table 11.

Inflow into the Everglades National Park (ENP) is mainly through structures S-12A, B, C, D, and E; S-18; S-197; S-332; S-174; S-175; S-332D; S-333; and S-334. The major inflow (70 percent) was through the S-12 structures. These structures are operated by the South Florida Water Management District for the U.S. Army Corps of Engineers in accordance with the Rain-Driven Water Deliveries Plan to the ENP and the Regulation Schedule of WCA-3A. The rainfall plan discharges through the S-333 and S-12A, B, C, and D structures are estimated a week in advance using a computer program. A weekly report is posted by the SFWMD (http://www.sfwmd.gov/org/ema/reports/sharkriver/index.html). The objective of the rainfall plan is to restore a more natural hydroperiod and hydropattern in the northeast Shark River Slough. Also, structural and operational modifications were incorporated into the delivery plan based on the Interim Operation Plan (IOP) for protection of the Cape Sable seaside sparrow (http://hpm.saj.usace.army.mil/i6ssueweb/Sparrow/fiopeis.htm). Flows through S-18 accounted for 13 percent of the total flow. Structures S-332D contributed 10 percent. Structure S333 and S334 contributed 7 percent with S-197 an S-174 adding minor inflows. The total surface water inflow to the Park for WY2004 was 1,251,807 ac-ft, which is 137 percent of WY2003 inflows (913,207 ac-ft). The historical average inflow is 1,168,966 ac-ft. **Figure 5-49** depicts historical monthly average inflows, and WY2004 and WY2003 inflows into the ENP. Monthly inflows to the ENP by water control structure are shown in Appendix 5-2, Table 12. **Figure 5-50** shows total surface water inflows and outflows to major hydrologic components.

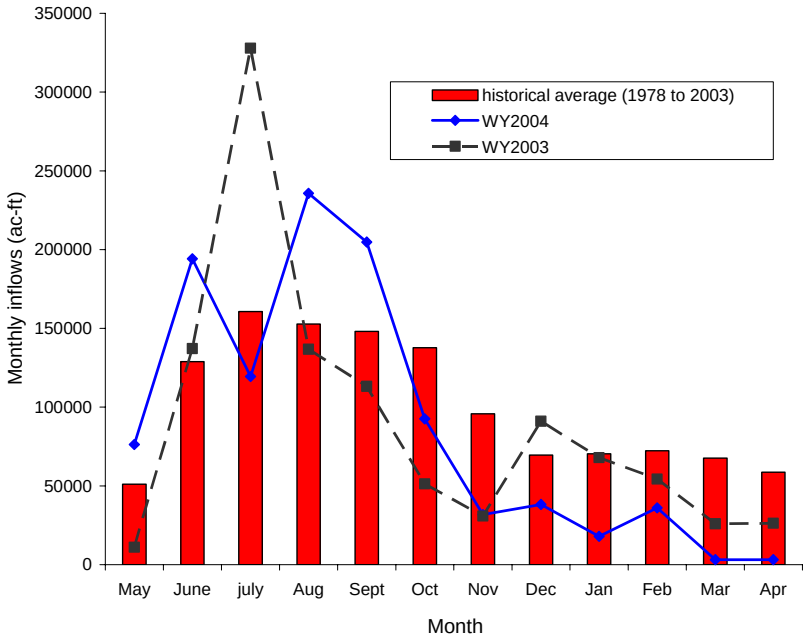

Figure 5-47. Monthly inflows into WCA-3.

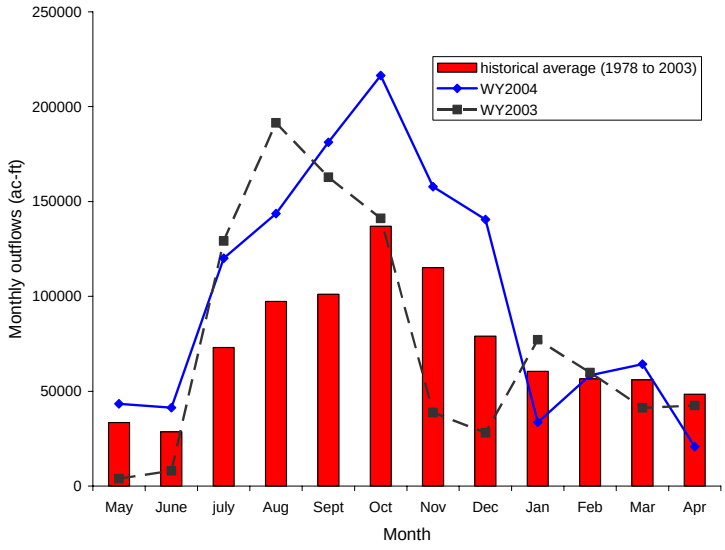

Figure 5-48. Monthly outflows from WCA-3.

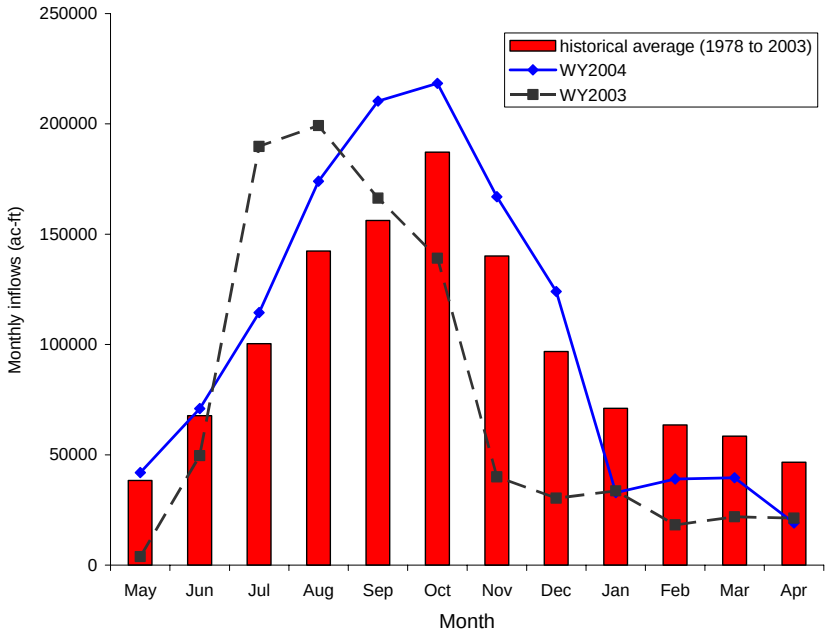

Figure 5-49. Monthly inflows into the ENP.

Figure 5-50. WY2004 inflow and outflows into major hydrologic components.

CONCLUSIONS

Hydrologic data is essential to the South Florida environmental restoration and water management efforts of the South Florida Water Management District. As such, this information is presented as a separate chapter in the *2005 South Florida Environmental Report – Volume I*. This chapter includes updated hydrologic data and analysis from the *2004 Everglades Consolidated Report* with expanded coverage to address the hydrology of the entire South Florida area within the District's boundaries. Rainfall, potential evapotranspiration, water levels, inflows, and outflows are presented for WY2004, and hydrologic conditions were compared with the previous water year, WY2003. Historical hydrologic data was also analyzed and compared with the current and previous water year's hydrology. However, it should be noted that given the extensive coverage for this year's report, the extent of data analysis is limited at this time.

During WY2004, rainfall in the Upper Kissimmee, Lower Kissimmee, and Lake Okeechobee rainfall areas was close to average. The east coast and the Everglades National Park had lower than average rainfall, whereas the west coast had higher than average rainfall. Potential evapotranspiration or evaporation from lakes, wetlands, and impoundments was close to the expected District-wide average (52.6 inches).

Monthly average water levels for WY2004 in most areas within the Upper Chain of Lakes (Lake Alligator, Lake Myrtle, Lake Mary Jane, Lake Gentry, Lake East Tohopekaliga, and Lake Tohopekaliga) were generally close to WY2003 levels and current regulation schedules except Lake Tohopekaliga. At Lake Tohopekaliga, ecological drawdown was implemented and deviations were made from the regular regulation schedule. A water level decline of approximately 4.5 ft resulted by late April 2004, as compared to WY2003. The Lake Istokpoga average water level was similar to that of WY2003. In contrast, the Lake Kissimmee average water level during WY2004 was lower than the WY2003 average stage, while the Lake Okeechobee average water level was higher.

During WY2004, WCA-1 maintained an average stage of 16.61 ft NGVD. This was slightly higher than the WY2003 average of 16.51 ft NGVD and higher than the historical average water level of 15.63 ft NGVD. The average water level in WCA-2 for the current reporting period was 12.40 ft NGVD. This was higher than the WY2003 average of 12.17 ft NGVD, but lower than the historical average water level of 12.58 ft NGVD. The average water level in WCA-3 in WY2004 was 10.30 ft NGVD. This was higher than the WY2003 average of 10.07 ft NGVD) and the historical average water level of 9.50 ft NGVD. The average water level in the ENP at site P33 in WY2004 was 6.68 ft NGVD, which was higher than the WY2003 average of 6.35 ft NGVD and the historical average water level of 5.96 ft NGVD. The average water level in the ENP at site P34 in WY2004 was 3.09 ft NGVD, which was also higher than the WY2003 average of 2.53 ft NGVD and the historical average water level of 2.04 ft NGVD.

During WY2004, surface water outflow through Lake Kissimmee was 1,193,153 ac-ft. Lake Istokpoga discharge was 401,631 ac-ft. Lake Okeechobee inflows totaled 2,920,448 ac-ft and outflows were 2,617,958 ac-ft. Discharge into the Southern Indian River Lagoon and St. Lucie Estuary was 1,103,338 ac-ft with 688,528 ac-ft discharged through the St. Lucie Canal outflow structure S-80. Discharge into the Caloosahatchee Estuary through structure S-79 was 2,445,277 ac-ft. For WCA-1, inflows were 334,957 ac-ft and outflows were 269,603 ac-ft; for WCA-2, inflows were 520,641 ac-ft and outflows were 749,663 ac-ft; and for WCA-3, inflows were 1,053,423 ac-ft and outflows were 1,221,322 ac-ft. Inflows to the ENP were 1,251,807 ac-ft. Overall, no extreme hydrologic event such as El Niño, La Niña, hurricanes, or drought occurred in South Florida during WY2004.

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